NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

COMPUTERIZED MEASUREMENT, DISPLAY AND ANALYSIS OF SONAR TRANSDUCER EQUIVALENT CIRCUIT PARAMETERS

by

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December 1982

Thesis Advisor: S. L. Garrett

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A126642	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Computerized Measurement, Display and Analysis of Sonar Transducer Equivalent Circuit Parameters		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis December 1982
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Leslie Jeanne Skowronek		8. CONTRACT OR GRANT NUMBER(s) N0001482WR20261
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 384-938
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE December 1982
		13. NUMBER OF PAGES 131
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

transduction	reactance	electromechanical coupling
admittance	conductance	hydrophone
resistance	susceptance	
impedance	resonance	projector

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Certain measurements of the electrical and mechanical properties of transducers are of importance to designers. These can be determined from accurate complex admittance and impedance measurements made throughout the frequency range of interest. Manual collection of needed data is a time-consuming process that is prone to error. The computerized system herein described substantially reduces the time requirement and produces more

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S/N 0102-014-6601

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Computerized Measurement, Display and Analysis of Sonar Transducer Equivalent Circuit Parameters

by

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

NAVAL POSTGRADUATE SCHOOL
December 1982

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ABSTRACT

Certain measurements of the electrical and mechanical properties of transducers are of importance to designers. These can be determined from accurate complex admittance and impedance measurements made throughout the frequency range of interest. Manual collection of needed data is a time-consuming process that is prone to error. The computerized system herein described substantially reduces the time requirement and produces more accurate output than can be obtained utilizing manual methods. In addition to a general discussion of equivalent circuits and the instruments employed, this report includes samples of plots and calculated parameters for piezoelectric and magnetostrictive transducers, the experimental comparison with traditional manual methods and the program listing for two versions of the system allowing varying amounts of operator options.

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ACKNOWLEDGEMENTS

I would like to acknowledge the support and assistance provided by Dr. Steven L. Garrett, my thesis advisor. I am extremely grateful for his help, information and continued interest in this project and for being a mainstay throughout the months of research and design. Also, I would like to acknowledge the assistance provided by Professor O. B. Wilson, Jr., whose shared knowledge of the theory and of transducers made this a fullfilling and worthwhile experience. I wish to extend my special thanks to Lieutenant Donald V. Conte, USN. His cooperation and assistance with the operation and programming of the HP-85 and his encouragement of an adaptation of parts of his thesis program proved large time savers and prevented a duplication of effort. I appreciate the support of the Naval Postgraduate School Foundation Research Program which provided the funds to purchase the computer and computer controllable instrumentation used in this project. I wish to thank Lieutenant Commander John Conner, Jr. for his help and friendship. My extra special thanks to R.T. who ensured I took time out to play, get fresh air, and relax thereby helping me through the rough times.

I. INTRODUCTION

Transduction is defined in an extremely general sense as any conversion of one form of energy into another. The devices responsible for this conversion, in either direction, are transducers. For this author, the interest is the conversion of electricity into sound and vice versa. Commonly, a transducer that converts electrical energy into sound is called a projector, loudspeaker, source or transmitter. Those serving the reverse function are commonly called hydrophones, microphones, or receivers. Some types of transducers are reversible and are capable of filling either role. This study is restricted to the analysis of reversible transducers.

A. MECHANISMS OF TRANSDUCTION

There are two basic types of mechanisms commonly used in reversible electroacoustic transducers designed for underwater sound, one involving interaction between mechanical motions and forces and electrostatic fields and the other between mechanical motions and forces and magnetic fields. Both types are amenable to analysis using equivalent electrical circuits; but, due to the basic

differences in conventions used to describe forces in electric and in magnetic fields, the details are different. Magnetically coupled transducers of the moving coil type have the diaphram attached to a wire coil suspended in a magnetic field. It is the interaction of the current in the coil and the magnetic field that induces a force on the coil and causes the diaphram to move and radiate an acoustic wave [Ref. 1]. These classifications may be further subdivided based on the motor mechanisms involved (i.e. electrodynamic, electrostatic, magnetic, magnetostrictive, and piezoelectric) [Ref. 2]. The classification systems for transducers vary depending upon the analysis being done. Descriptions of various classifications are presented by the previous references as well as by Heaslip [Ref. 3], and Sherman [Ref. 4].

B. PURPOSE OF THIS STUDY

All electroacoustic transducers may be considered as being composed of electrical elements so that the analysis of the transducer is greatly simplified if an equivalent electrical circuit is used.

While the most common transducers currently in use in underwater sound are made of piezoelectric materials, the

aim of this study is to provide a generalized, semiautomated means of obtaining meaningful transducer measurements on any type of transducer with the operator having minimal knowledge of the device.

The equipment set-up utilizes basic devices (e.g. voltmeter, sweep oscillator, Dranetz impedance meter, amplifier) interfaced to, and controlled by, a desk-top computer. This interfacing provides more precise data acquisition than can be obtained from manual plots interpreted by an operator. The time saving factor is a major motivation for this choice.

Certain measurements of the electrical and mechanical properties of the transducer are of importance to designers. In some cases, it is desireable to have the resonant frequency fall within a particular range. More likely, there will be concern for a high electromechanical coupling coefficient. Efficiency may be the major concern or perhaps it is desired to have high losses and, therefore, a low mechanical quality factor with consequent "flatness" of response [Ref. 5].

Direct measurement of these values is not always possible. However, many of the electrical component values

needed to calculate mechanical parameters can be readily obtained from properly annotated impedance and admittance plots for a particular transducer.

Currently, there are automated systems designed to analyze transducers, such as the WQM-12 [Ref. 6]. Few are small enough to be readily transported to the transducer as is this system.

C. FORMAT OF THE REPORT

The basic physical and electrical theory used in preparation of this report is presented in Chapter II. While more thorough analyses of transducers and equivalent circuits may be found in some of the references, only data pertinent to the measurements obtained by this system are presented.

Chapter III explains the interfacing between various components of the equipment set-up and the computer. The operator/computer interaction is also addressed. Representative samples of computer output are included.

Chapter IV briefly describes the testing and evaluation of the system and program. The results and conclusions are presented here.

The computer programs written in BASIC computer language are included in Appendix A.

II. THEORY

Since much of the physics and engineering involved in discussions of transducers is common to both electric-coupled and magnetic-coupled transducers, this report will make a general approach and point out differences where they occur. Table I, at the end of this chapter, contains a listing of symbols used in this report and refers to symbology used in some of the references cited.

A. GENERAL

The approach usually taken in electroacoustic analysis is to use an electric circuit to model the transducer. In simplest form one may use a two-port network with one port representing the electrical terminals and the other the mechanical terminals. Analogs for force and speed may be voltage and current or vice versa depending on the type of transducer.

The canonical equations describing the behavior of the two port transducer may be written as:

$$V = Z_o \cdot I + T_{em} \cdot U \tag{2.1}$$

and

$$F = T_{me} \cdot I + Z_m \cdot U \tag{2.2}$$

where V and I are the voltage and current at the electrical port and F and U are the force and velocity at the mechanical port. T_{em} is a transduction coefficient relating the electromotive force at the electrical port to the velocity in the mechanical net, and T_{me} is a transduction coefficient that relates the force developed at the mechanical port of a two-port network to the current in the electrical mesh [Ref. 8]. Φ is the transformation factor and may be defined as $\Phi = T_{em}/Z_o$. The canonical equations for a magnetically coupled transducer of the moving coil type are:

$$F = -B \cdot l \cdot I + Z_m \cdot U \tag{2.3}$$

$$V = Z_o \cdot I + B \cdot l \cdot U \tag{2.4}$$

where B is the magnetic field and l is the length of the wire in the coil. (Note: This choice is valid for electrodynamic transducers (moving coil) as written using $B \cdot l = T_{em}$. Magnetostrictive transducers obey the same set of equations but $T_{em} \neq B \cdot l$.)

For electromechanical coupling, Figure 2.1 shows typical circuits and transformations [Ref. 7].

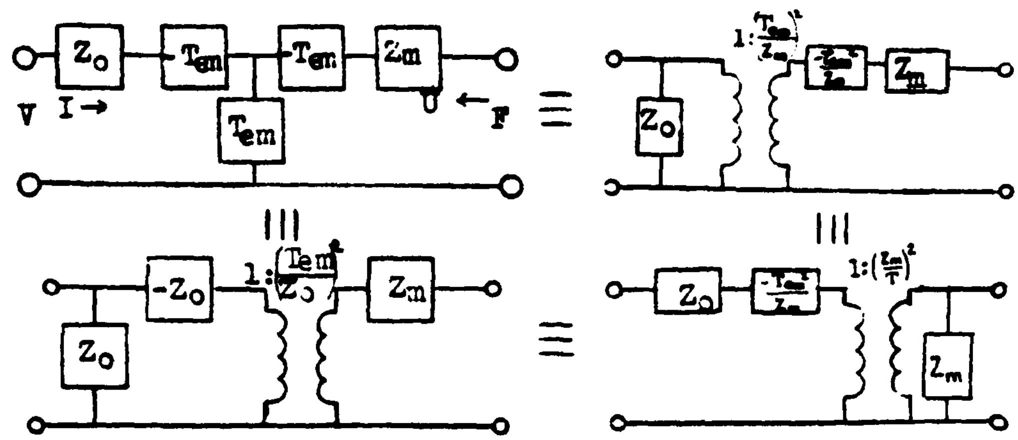


Fig. 2.1. Typical Circuits and Transformations

In the vicinity of resonance, which is of concern here, the Mason circuit or modified Van Dyke circuit is valid. It is also valid for low frequency values which will also be needed for some calculations [Ref. 8]. This circuit is shown in Figure 2.2 where L_m, R_m, and C_m represent mechanical values. C_o is the clamped or blocked or shunt capacitance.

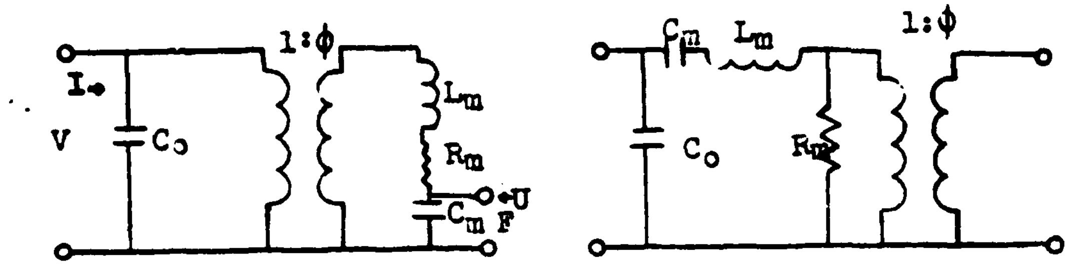


Figure 2.2. (a). Modified Van Dyke or Mason circuit (b). Basic Transducer Circuit.

Kinsler, and others [Ref. 1], define the following measurable mechanical and electrical impedances of a system:

Blocked electrical impedance (ohms) $= Z_o = V/I|_{U=0}$ (2.5)

Free electrical impedance (ohms) $= Z = V/I|_{F=0}$ (2.6)

Open circuit mechanical impedance (N·s/m) $= Z_m = F/U|_{I=0}$ (2.7)

Short circuit mechanical impedance $(N \cdot s/m) = Z_{mm} = F/U|_{V=0}$ (2.8)

Magnetically coupled transducers may be represented by the circuit of Figure 2.3, where Φ_m is a transformation factor. $\Phi_m = B \cdot l$ for moving coil transducers [Ref. 2].

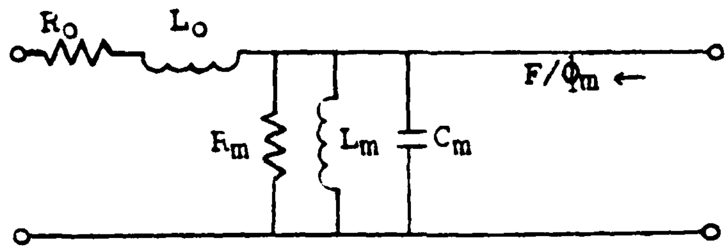


Figure 2.3. Equivalent Circuit for a Magnetically Coupled Transducer.

Important properties of the transducer may be found by studying the electrical impedance of the system as a function of driving frequency. The unloaded driving point electrical impedance may be determined from the canonical equations (2.1-2.4) and is given by

$$Z = V/I|_{F=0} = Z_o + (-T_{em}T_{me}/Z_m) \tag{2.9}$$

Similarly, the short circuit mechanical driving point impedance is given by

$$Z_{mm} = F/U|_{V=0} = Z_m + (-T_{em} \cdot T_{me})/Z_o \qquad (2.10)$$

The electrical impedance is influenced by the motion of the coupled mechanical system, as indicated by the second term on the right hand side. This term is referred to as the motional impedance, and defined by Hunt [Ref. 2], as

$$Z_{mot} = (-T_{em} \cdot T_{me})(1/Z_m) \qquad (2.11)$$

Similarly, the mechanical driving point impedance is influenced by the electrical load.

B. USE OF COMPLEX IMPEDANCE/ADMITTANCE PLOTS

1. The Resonance Circle

Graphical displays of impedance and admittance data can be extremely useful in the analysis of a transducer. When properly scaled and annotated, quantitative results may be obtained from the diagrams. Generally, in the vicinity of resonance, the element is regarded as having a single degree of freedom and the locus of points of the complex impedance is a circle in the neighborhood of the resonance frequency [Ref. 7], [Ref. 8]. Figure 2.4 and Figure 2.5 are typical resonance circle diagrams where, in Figure 2.4,

the electrical reactance is plotted as a function of electrical resistance with frequency as a parameter [Ref. 8]. F4 and f5 are the frequencies of the half power points and f8 is the resonance frequency. Dashed lines show the same transducer under load conditions.

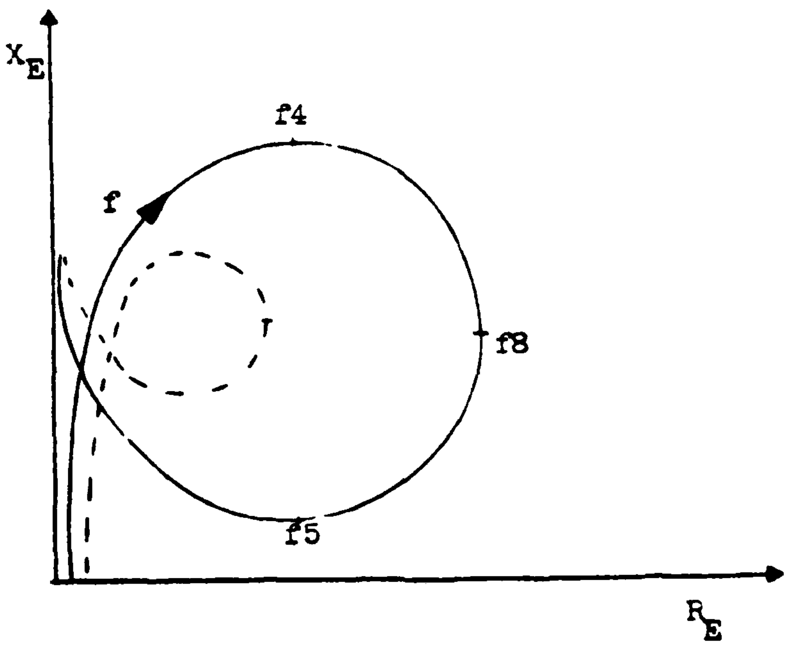


Fig. 2.4. Complex Impedance Diagram

(Note: Reactance may be entirely negative for an electrically coupled transducer).

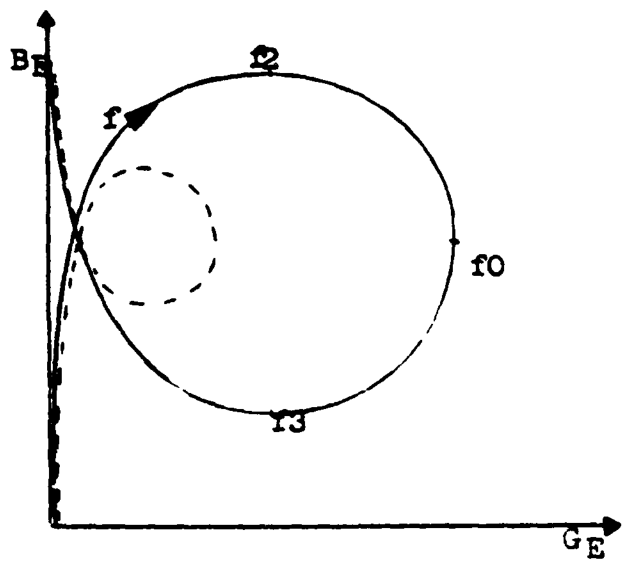


Fig. 2.5. Complex Admittance Diagram

In Figure 2.5, f2 and f3 equate to the frequencies of the half power points. F0 is the frequency of resonance. The dashed line would be the same ideal transducer tested under load conditions. (Note: Susceptance may be entirely negative for a magnetically coupled transducer.)

Motional impedance components may be obtained using the following formulae:

$$R_{mot} = R_E - R_o \tag{2.12}$$

$$X_{mot} = X_E + j\omega L_o \tag{2.13}$$

with $$Z_{mot} = R_{mot} + jX_{mot} \tag{2.14}$$

The motional admittance components are given by:

$$G_{mot} = G_E - (1/R_o) \tag{2.15}$$

$$B_{mot} = B_E - j\omega C_o \tag{2.16}$$

with $$Y_{mot} = G_{mot} - jB_{mot} \tag{2.17}$$

The frequency of maximum power output at constant voltage input is called the mechanical resonance and is represented in Figure 2.6 by f8 [Ref. 9].

In the motional admittance diagram, Figure 2.7, f0 is the frequency of maximum conductance and resonance. F2 and f3 are the half power points.

2. Component Responses

Impedance measurements are made at the electrical terminals of the transducer. The behavior of the real and

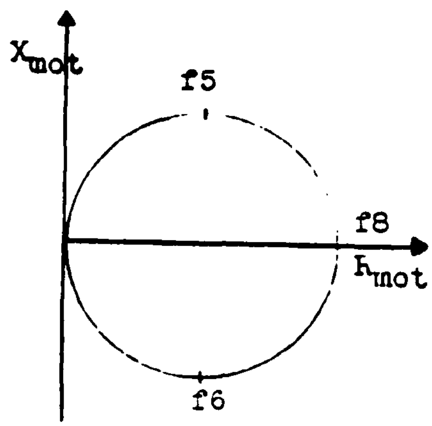


Fig. 2.6. Motional Impedance Diagram

imaginary components of the complex impedance may be observed as the frequency spectrum is swept at a sufficiently slow rate so that the system is quasi-steady-state. When the mechanical system is clamped so that it cannot move, the blocked electrical impedance may be measured and used to calculate motional impedance. Since it is difficult to adequately clamp a device over the entire frequency spectrum, values may be obtained far above and below resonance and the intermediate values inferred. This

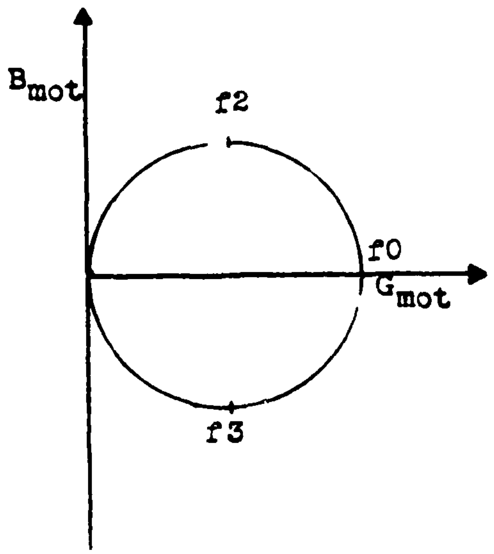


Fig. 2.7. Motional Admittance Diagram

is especially important for the reactance and susceptance curves whose clamped values vary more drastically with frequency than do the real components of admittance or impedance.

The maximum value of motional impedance will equate to the mechanical resistance and is the diameter of the circle. This value will be of importance in calculating the efficiency of the system.

Plots of various input electrical parameters (conductance (G_E) and susceptance (B_E) or resistance (R_E) and reactance (X_E) versus frequency) can provide all of the information necessary to obtain the electrical and mechanical quality factors for the system. These values indicate the sharpness of the resonance.

a. Impedance

The circuit of Figure 2.8 is useful for analysis of the behavior in the vicinity of resonance.

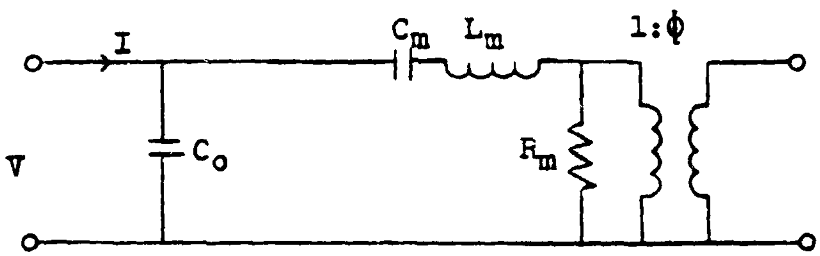


Fig. 2.8. Equivalent Circuit Diagram

A plot of the input electrical impedance components versus frequency will resemble Figure 2.9.

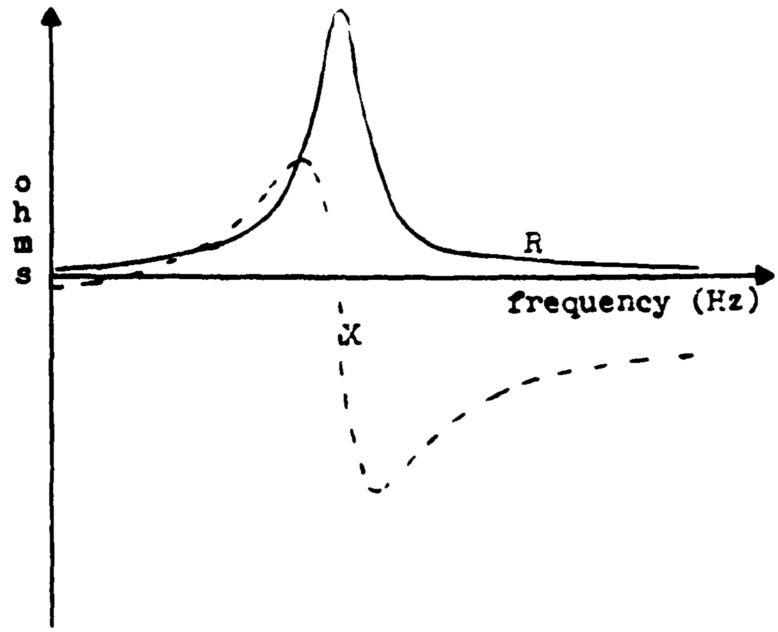


Fig. 2.9. Resistance and Reactance Plotted Versus Frequency

b. Admittance

The motional admittance equations are

$$Y_{mot} = G_{mot} + jB_{mot} = \frac{1}{R_{mot} + jX_{mot}} \frac{R_{mot} - jX_{mot}}{R_{mot} - jX_{mot}} =$$

$$= \frac{R_{mot}}{R_{mot}^2 + X_{mot}^2} + j\frac{-X_{mot}}{R_{mot}^2 + X_{mot}^2} \qquad (2.18)$$

Plots of conductance and susceptance versus frequency for Figure 2.8 will resemble Figure 2.10. The frequencies where the susceptance (B) is zero correspond to the electrical resonance and antiresonance frequencies.

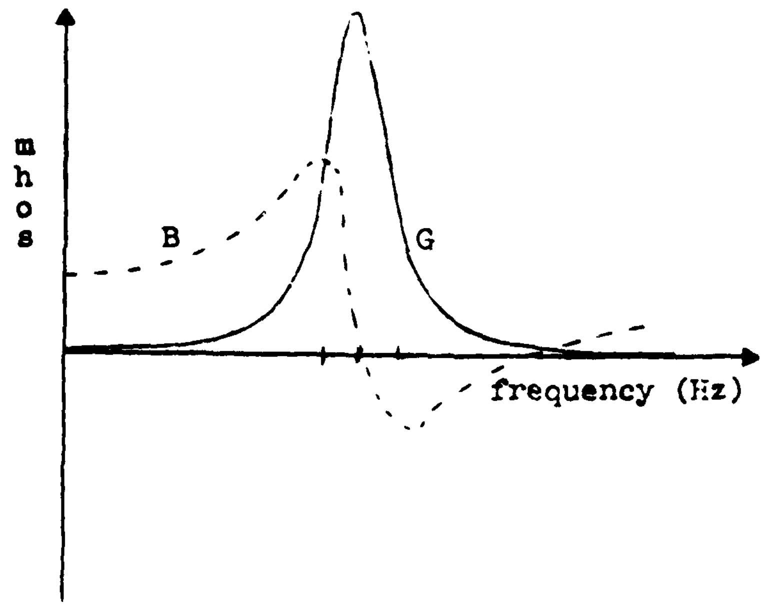


Figure 2.10. Conductance and Susceptance Plotted Versus Frequency

C. EVALUATION OF TRANSDUCER PARAMETERS

This system is designed to obtain useful information on devices used in transmitting and receiving in water. As

such, it is first necessary to obtain data in an unloaded situation in order to be able to separate the effects of acoustic loading. For transducers designed for use in water, air normally provides an adequate medium for evaluation of the acoustically unloaded properties. Placing the transducer in water means the two-port network will now reflect the sum of the mechanical and the load impedances. Then, according to Hunt [Ref. 2],

$$Z_T = Z_m + Z_l = (R_m + R_l) + j(X_m + X_l) \tag{2.19}$$

or

$$Z_m + Z_l = (R_m + R_l)(1 + j \cdot 2 \cdot Q \cdot p) \tag{2.20}$$

where p is a frequency parameter--($p=.5((\omega/\omega_o)-(\omega_o/\omega))$ and Q is the quality factor measured for the resonance (i.e. electrical or mechanical depending on the type of measurements).

Data obtainable from admittance measurements will provide needed values for determining the motional admittance circle. The maximum value of conductance will occur at the frequency of electical resonance. The quality factor can be determined from the frequencies at which the conductance assumes half the diffference of its maximum

value and its blocked value (i.e. $Q = f_r/(f_u - f_l)$. These frequencies will also coincide with the frequencies (f2 and f3) of the local maximum and minimum susceptance values near resonance. Blocked capacitance may be calculated from measurements of susceptance far above and/or below resonance. For an electrically coupled transducer with small dielectric losses, valid measurements of C_o may be made very far below resonance. For magnetic coupling, measurements must be taken far above and far below resonance and the values between interpolated linearly between these two.

Impedance data will provide the frequency of antiresonance. The frequencies of the half values for the difference between the maximum resistance and the blocked resistance will correspond to the maximum and minimum values of reactance and allow for calculation of a mechanical quality factor. Blocked capacitance or inductance (depending on the type of transducer) may be calculated from reactance data obtained far above and/or below resonance.

The following paragraphs briefly describe the definition and calculation of various constants.

1. Quality Factor = Q

This factor indicates the sharpness of resonance.

$$Q = \frac{\text{frequency of max. G or R}}{\text{freq. difference of min. and max. B or X}} = \frac{f(\text{resonance})}{f(\text{upper}) - f(\text{lower})} \tag{2.21}$$

2. Electromechanical coupling coefficient = $K^2(\text{eff})$

This coefficient indicates how tightly the electrical and mechanical meshes are coupled [Ref. 2].

$$K^2(\text{eff}) = 1-(fB/f0)^2 \quad \text{for electromagnetic coupling} \tag{2.22}$$

and

$$K^2(\text{eff}) = 1-(f0/fB)^2 \quad \text{for electrostatic coupling} \tag{2.23}$$

where fB is used to indicate the frequency of maximum resistance and f0 indicates the frequency of maximum conductance.

3. Static Coupling Coefficient = K^2

This term is the ratio of the stored mechanical energy to the total energy stored in the device [Ref. 1], [Ref. 5].

$$K^2 = \frac{C_1}{C_o + C_1} \qquad (2.24)$$

4. Shunt Capacitance = C_o

This is the blocked capacitance of the system. There is no simple method of measuring this quantity (with the possible exception of instruments designed for a specific frequency). Measurements must be made at a frequency far removed from frequencies of mechanical resonance in order to minimize the effects of electromechanical coupling. If the capacitance ratio (C_1/C_o) is greater than fifty, the inaccuracy should be minimal and may be considered negligible.

$$C_o = \frac{1}{\omega X_o} = \frac{B}{\omega} \qquad \text{where } \omega << \omega_o \qquad (2.25)$$

5. Clamped Resistance and Reactance = R_o and X_o

R_o and X_o may be closely approximated by obtaining data far below and above resonance and interpolating between since there is a positive frequency dependence. However, for many practical purposes, (and for electrically coupled transducers), data may be obtained far below resonance which

provides a reasonable approximation to the actual value throughout the frequency range of interest. These values are assumed to represent those which would be measured if the mechanical parts of the system were blocked or clamped to prevent motion.

6. Blocked Inductance = L_o

This is the inductance of the blocked system (usually with magnetic coupling) and is obtainable from data collected far below and above resonance.

$$L = \frac{X(\text{interpolated})}{\omega_o} \tag{2.26}$$

7. Capacitance Ratio = 'R'

This is the ratio of the blocked capacitance (C_o) to the motional capacitance (C_1).

$$'R' = \frac{C_o}{C_1} = \frac{PI}{8}\;\frac{(1-K^2)}{K^2} \qquad \text{where } K^2 \text{ is the static coupling coefficient} \tag{2.27}$$

8. <u>Figure of Merit</u>

The figure of merit is little mentioned in the references probably because it is an arbitrary formula depending upon a designer's criteria. Miller [Ref. 5], mentions $K^2 \cdot Q_m$ as one possibility and utilization of the coupling coefficient as another. No specific calculation of this value is done in this report, leaving it to the user to insert as desired.

9. <u>Diameters</u>

Impedance or admittance circles are transformed to motional diagrams by subtracting blocked values or blocked values multiplied by angular frequency as discussed in section B.1 above. The diameters of the resulting circles will provide needed values for efficiency calculations. D_w and D_A signify the diameters of the motional circle for the transducer in water and in air, respectively.

D. EFFICIENCY

The overall efficiency of a transducer is the ratio of the power delivered to an external load connected at the output terminals to the total power at the input.

At resonance, this can be easily calculated from known values. For an electrically coupled transducer, the efficiency is given by:

$$E = \frac{D_w(D_A - D_w)}{G\ D_A} \qquad (2.28)$$

where D_A and D_w are the diameters of the motional admittance circles and where G is the conductance at resonance.

Similarly, the efficiency at resonance for a magnetically coupled transducer is given by:

$$E = \frac{D_w(D_A - D_w)}{R \cdot D_A} \qquad (2.29)$$

where these are diameters of the motional impedance circles and R is the resistance at resonance [Ref. 10].

The mechanical power utilization factor is part of the overall efficiency. It is given by $R_l/(R_l+R_m)$ which can be expressed in terms of loaded and unloaded values of Q or by the diameters of circles.

$$\frac{R_l}{R_m + R_l} = \frac{D_A - D_w}{D_A} = \frac{Q_A - Q_w}{Q_A} \qquad (2.30)$$

(Note: All values should be taken from either admittance data or impedance data but should not be mixed.)

Once the efficiency at resonance is determined, utilization of the impedance data of a magnetically coupled transducer allows for calculation of the lagging phase angle (β).

$$\beta = 0.5 \cdot \mathrm{ArcCos}\ ((R_{res} - R_o)/D_w) \tag{2.31}$$

The frequency parameter for maximum efficiency may be calculated as

$$p = (D_w \mathrm{Sin}(2 \cdot \beta))/(4 \cdot R_o \cdot Q_w) \tag{2.32}$$

and from the earlier relationship between p and the frequency ratios, the frequency for maximum efficiency for a magnetically coupled transducer may be calculated.

$$f = f0\ (2 \cdot p + (p^2 + 1)^{1/2}) \tag{2.33}$$

The frequency of maximum efficiency may not coincide with either the resonant frequency or the frequency of maximum admittance. For the magnetostrictive transducer, this frequency of maximum efficiency is usually greater than that at resonance.

A development by Camp [Ref. 8], shows that a magnetostrictive transducer may produce more acoustic power at the resonant frequency even though efficiency may be less. Normally, the frequency for optimum acoustic power will fall between the mechanical resonance frequency and the frequency of optimum efficiency. This is due to eddy current losses and magnetic hysteresis.

Since transduction losses are low, maximum power output for piezoelectric devices is limited mainly by voltage limits. The optimum operating frequency is accepted as the frequency of maximum admittance [Ref. 8].

If one assumes that the transducer has a high Q (sharp resonance) and that the blocked resistance is constant throughout the frequency range for the impedance circle, then the potential efficiency may be expressed as

$$\text{Pot. Eff.} = \frac{(R_{max})^{1/2} - (R_{min})^{1/2}}{(R_{max})^{1/2} + (R_{min})^{1/2}} \tag{2.34}$$

The potential efficiency represents the maximum efficiency available for the most favorable loading conditions. This equation deletes the requirement for data from a loaded

condition but requires the air motional impedance loop to very closely approximate a circle [Ref. 9]. "High Q" as used here implies values greater than thirty. If the air motional impedance loop is not approximately circular and/or the Q is low, then, from reference 2,

$$\text{Pot. Eff.} = \frac{\left(1 + \frac{D_A}{R_0} \cos^2 \beta\right)^{1/2} - \left(1 - \frac{D_A}{R_0} \sin^2 \beta\right)^{1/2}}{\left(1 + \frac{D_A}{R_0} \cos^2 \beta\right)^{1/2} + \left(1 - \frac{D_A}{R_0} \sin^2 \beta\right)^{1/2}} \tag{2.35}$$

E. SUMMARY

There is helpful information to be obtained from both impedance and admittance data. Some transducers more readily reveal properties through one type of diagram than another. Normally, admittance data is collected for electrically coupled systems, while impedance data is better for studying magnetically coupled systems [Ref. 2]. Due to the ease of obtaining data with the system proposed here, both sets of data and diagrams may be rapidly obtained.

TABLE I
COMPARATIVE SYMBOLOGY

	HUNT [REF. 2]	IRE [REF. 11]	K.F.C.S * [REF. 1]	MILLER [REF. 5]	ALBERS [REF. 9]	CAMP [REF. 8]	CADY [REF. 7]	THIS RPT
Blocked Resistance	R_e	---	R_b	R_b	R_b	R_e	R′	R0/R9
Blocked Inductance	---	---	L_b	---	L_b	L_e	L′	L0
Blocked Capacitance	C	C_b	C_b	C_b	C_b	C_b	C	C0
Blocked Reactance	X_e	---	---	X_b	X_b	---	---	X0/X9
Blocked Conductance	G_e	---	---	G_b	---	---	---	G0/G9
Blocked Susceptance	B_e	---	---	B_b	---	---	---	B0/B9
Blocked Admittance	Y_e	---	Y_{EB}	---	Y_o	Y_e	---	Y_o
Blocked Impedance	Z_e	---	Z_{EB}	---	Z_b	Z_e	---	Z_b
Driving Pt. Admittance	Y_{ee}	Y	Y_E	Y_{IN}	---	Y_i	Y	Y
Driving Pt. Impedance	Z_{ee}	Z	Z_{EF}	Z_{IN}	Z	Z_i	Z	Z
Input Elec. Resistance	R_{ee}	R_e	R_E	R_{IN}	R_i	R_i	R	R_E
Input Elec. Reactance	X_{ee}	X_e	X_E	X_{IN}	X_i	---	X	X_E
Input Elec. Conductance	G_{ee}	---	G_E	G_{IN}	---	---	g	G_E
Input Elec. Susceptance	---	---	B_E	B_{IN}	---	---	b	B_E

TABLE I (CONT)

	HUNT [REF. 2]	IRE [REF. 11]	K.F.C.S * [REF. 1]	MILLER [REF. 5]	ALBERS [REF. 9]	CAMP [REF. 8]	CADY [REF. 7]	THIS RPT
Open ckt. Mech. Imped.	Z_m	--	Z_{mo}	Z_{oc}	Z_m	Z_m	--	Z_m
Short ckt. Mech. Imped.	Z_{mm}	--	Z_{ms}	Z_{sc}	Z_m'	Z_{mm}	--	Z_{mm}
Mechanical Resistance	R_m	--	R_m	R_m	R_m	R_m	--	R_m
Mechanical Capacitance	C_m	C_1	C	C_m	C	C	C_1	C_1
Motional Impedance	Z_{mot}	--	Z_{mot}	--	Z_{mot}	Z_{mot}	--	Z_{mot}
Motional Admittance	Y_{mot}	--	Y_{mot}	--	--	Y_{mot}	--	Y_{mot}
Motional Resistance	R_{mot}	R_1	R_{mot}	--	R_e	R_{mot}	--	R_{mot}
Motional Reactance	X	--	X	--	X_e	X_{mot}	--	X_{mot}
Motional Conductance	--	--	G_{mot}	--	--	G_{mot}	--	G_{mot}
Motional Susceptance	--	--	B_{mot}	--	--	B_{mot}	--	B_{mot}
Mechanical Resonance	f_R	f_p	$w/2\pi$	f_o	$w/2\pi$	f_R	f_n	F8/F9
Electrical Resonance	f_Y	f_s	--	f_Y	--	f_Y	f_o	F0/F1
Mechanical Quality Factor	Q	Q	Q_m	Q_m	--	Q_m	Q	Q8/Q9
Electrical Quality Factor	--	--	--	Q_E	--	--	--	Q0/Q1

TABLE I (CONT)

	HUNT [REF. 2]	IRE [REF. 11]	K.F.C.S * [REF. 1]	MILLER [REF. 5]	ALBERS [REF. 9]	CAMP [REF. 8]	CADY [REF. 7]	THIS RPT
Dynamic Elec. Mech. Coupling Coefficient	K_{eff}^2	--	K_{eff}^2	K_b^2	K_c^2	K_{eff}^2	--	K_{eff}^2
Static Coupling Coefficient	--	--	K_c^2	K^2	K^2	--	--	K^2
Transformation Coefficient	$\frac{T^2}{Z_e}$	--	Φ	Φ	--	Φ	--	Φ
Transduction Coefficient	T_{em} T_{me}	-- --	T_{em} T_{me}	-- --	-- --	T_{em} T_{me}	-- --	T_{em} T_{me}
Freq. Max. G	--	f_r	$w/2\pi$	f_r	--	f_o	f_o	f0/f1
Freq. Max. R	--	f_a	$w/2\pi$	f_a	--	f_o	f_n	f8/f9
Freq. Max. X	--	--	$w/2\pi$	f_3	--	f_1	f_1	f4
Freq. Max. B	--	--	$w/2\pi$	f_1	--	f_1	f_m	f2
Freq. Min. X	--	--	$w/2\pi$	f_4	--	f_2	f_2	f5
Freq. Min. B	--	--	$w/2\pi$	f_2	--	f_2	f_n	f3
Diameter of Circle (air)	D_V	--	--	--	d_A	D_a	--	D3
Diameter of Circle (water)	D_L	--	--	--	d_W	D_w	--	D4

* Kinsler, Frey, Coppens, and Sanders

III. ADAPTATION TO A COMPUTERIZED SYSTEM

In-phase and out-of-phase components of the admittance or impedance are needed in the analysis of a transducer. An initial attempt was made to use a lock-in analyzer, but ultimately a Dranetz impedance meter was used.

A. EQUIPMENT SET-UP

Data needed for the calculation of properties of transducers may be obtained using a lock-in analyzer. The magnitude and phase or in-phase and quadrature components will indicate resonances and provide the necessary information.

The initial set-up utilized the Princeton Applied Research Company Model 5204 Lock-in Analyzer. Phase information would have allowed for desired calculations. In experimentation, the circuit required for obtaining valid phase information became too complex to be practical. The lock-in analyzer is designed to operate in the 1 Hz to 100 KHz frequency range although it was determined to be accurate at higher frequencies. At low frequencies, there is a low source resistance and the signal to noise ratio

became too small to provide a reference. It was concluded that complex impedance measurements would be another means of getting the necessary data.

As briefly mentioned in the introduction, there are many methods for obtaining impedance information. Since this author desired a portable system usable for underwater transducers, a bridge network seemed reasonable.

The set-up used to design this system is shown in Figure 3.1. The Hewlett-Packard HP-85 computer directs the peripherals for the data taking. The printer and plotter are non-essential to the system and were used to provide larger format graphics and printout than are available with the built in thermal printer provided with the HP-85.

1. <u>Hewlett-Packard HP-85 Computer</u>

The HP-85 is an eight bit microcomputer that utilizes BASIC computer language. It has a 127 millimeter diagonal black and white electromagnetic-deflection CRT. A 32 character per line thermal printer/plotter is part of the unit. The computer has 16K bytes of read/write memory of which 14,579 are available to the operator. For this program a memory module is needed to expand the memory to 32K bytes. Programs or data may be stored on, or read from,

magnetic tape cartridges. To interface with peripheral equipment, an I/O ROM and an interface card were added to provide HP-IB (IEEE-488) instrumentation interface capabilities.

2. Synthesizer/Function Generator

The Hewlett-Packard Model 3325A Synthesizer/Function Generator can produce five different continuous waveforms. For this application a sine wave was desired for which this instrument has a frequency range of 1 microhertz to 20 megahertz. Frequency may be specified with up to eleven digits of resolution. Output amplitude is 1 millivolt to 10 volts peak-to-peak into a fifty ohm load. This model is fully programmable through the rear panel Hewlett-Packard Interface Bus (HP-IB).

3. Dranetz Complex Impedance--Admittance Meter

The Model 100C Complex Impedance--Admittance Meter (CIAM-100C) is a transistorized instrument that measures vector impedance, vector admittance, vector amplitude and phase. It covers a frequency range from 100 Hz to 200 KHz in three ranges of 0.1 to 2 KHz, 1 to 20 KHz and 10 to 200KHz. For measuring impedance a constant current is produced in the unknown impedance. The amplitude of the

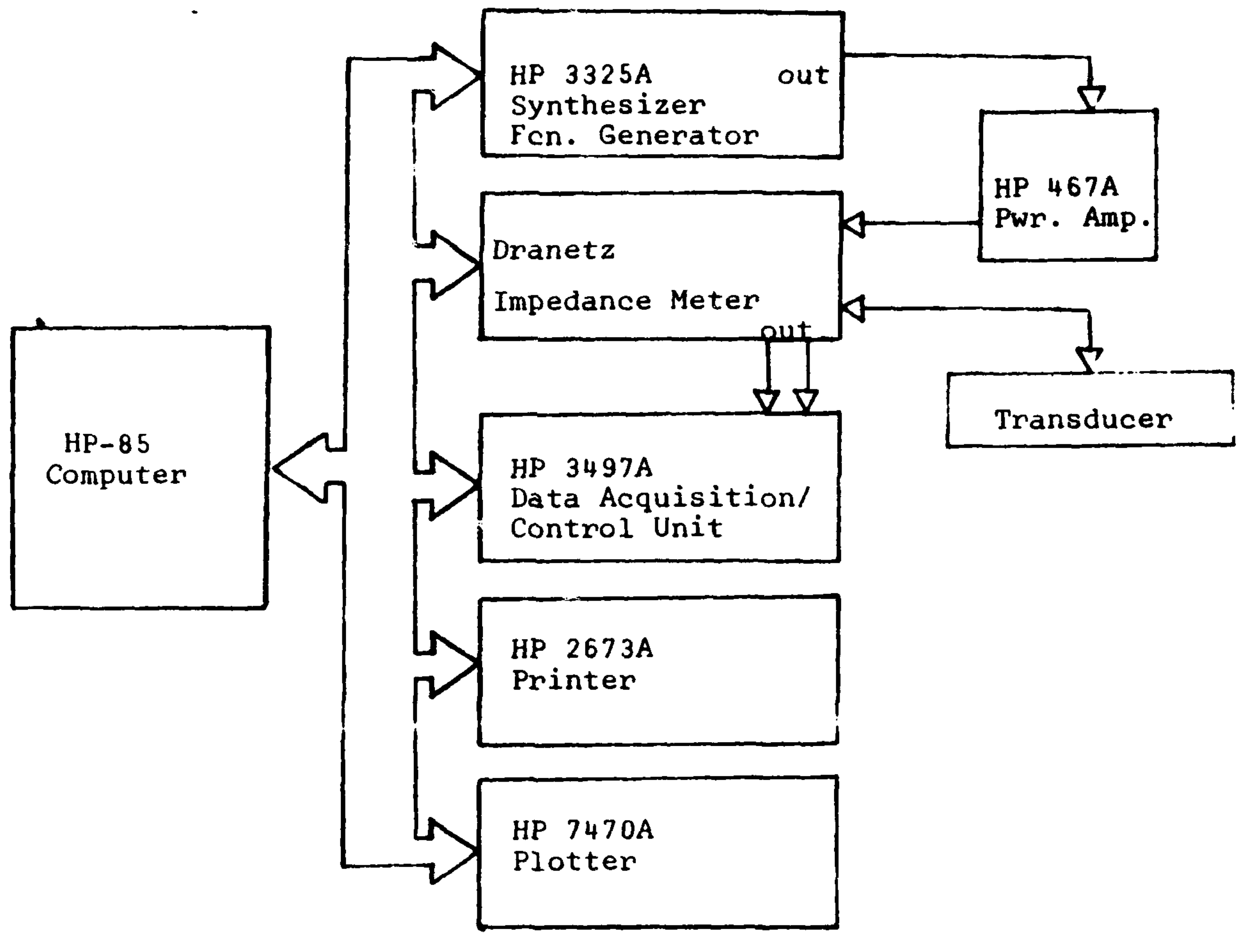


Figure 3.1 Equipment Set-up

current is set by the range switch. The voltage developed across the unknown impedance is amplified and fed to two resolvers. For measuring admittance, a constant voltage is applied to the unknown. The current through the unknown is measured by means of voltage developed across a small range-selected resistor placed in series with the unknown. The resolver outputs are proportional to conductance and susceptance of the unknown. The claimed accuracy of the instrument is plus or minus two percent full scale amplitude. The Dranetz meter requires an input signal voltage of 3 Vrms. In taking measurements on an unknown transducer, initially the frequency of interest may not be known as well as the appropriate scale settings for the meter. Measurements made on the Dranetz meter using a variable resistance box and voltmeters indicate linearity throughout the range settings. However, it is necessary to insure measurements do not cause either meter range to be exceeded. The limit indicator lights are activated when the unknown impedance or admittance is substantially greater than the full scale setting. When this occurs, an internal relay shunts the meters and the DC output terminals to zero.

4. <u>Data Acquisition/Control Unit</u>

The Hewlett-Packard Model 3497A Data Acquisition/Control Unit is used here as a voltmeter and scanner to measure the DC output voltage proportional to the deflection of the meters of the Dranetz. The instrument measures and displays voltage values to five and one half digits. It is internally triggered by software command during the data taking but takes the next reading as soon as the first is completed for obtaining averages.

5. <u>Power Amplifier</u>

This instrument is not essential to the operation of the system. The Dranetz meter is designed to accept direct ac voltage input; however, the particular meter used exhibited more stability when the amplifier was included in the set-up. The amplifier had unity gain and was only used to lower the effective output impedance of the frequency synthesizer from fifty ohms to two milliohms.

6. <u>General Discussion</u>

This equipment set-up is suitable for an initial system. A system designed for regular and routine use should include a different impedance measuring system than the Dranetz. Because of the design feature of the Dranetz,

a great deal of operator interface is required to change the various different scale and range factors which cannot be set directly by the computer. It is too easy for an operator to miss changing one setting or to overlap frequency range scales in the spectrum sweep and, thereby, obtain erroneous data. Also, the scale factors must be manually entered prior to the computer doing any calculations. The Dranetz also had annoying features, such as drift of the zero, excessive noise on low impedance ranges, and DC output at full scale deflection of 0.8 - 0.95 volts.

B. DISCUSSION OF THE PROGRAM

The HP-85 is the controlling unit directing the other instruments to take or send data as needed. Memory storage is handled by this microcomputer.

The goal was to design a program than would minimize the time necessary to collect pertinent data while maximizing accuracy. The program was to accommodate different media, allow for collection of admittance or impedance data or both, and work for transducers with either electric or magnetic coupling, while being easy to operate. This was accomplished; but due to the large differences in properties of different transducers, a second program was written to be used by more experienced operators.

One program is designed so that a person with minimal knowledge of the transducer or measurement procedures may run it and obtain meaningful information. It is suggested that the operator be familiar with the operation of the interfacing instruments (especially the Dranetz meter). An equivalent program is designed so that the operator may select the bandwidth for data collection and may specify the frequency for measurement of the blocked values (done as a percentage of the resonant frequency).

The program is broken into three sections. The first gives the operator an overview of the conductance and resistance of the transducer under test. Part two is the data collection for desired measurements with options for plots and lists of the data. The final section performs the calculations for motional data, efficiencies, and other desired outputs. The following subdivisions address the program in detail. Figure 3.2 is a flow chart of the program. The programs written in BASIC are included as Appendix A.

1. <u>The Search</u>

This first portion has been included to allow for visual and graphic display of the response of the transducer

over a selected frequency range. The operator is required to insert information on the type of coupling (magnetic or electric) of the transducer and the medium (air or water) in which measurements are to be taken. The operator is instructed to set the Dranetz for the measurement of admittance data and to specify the range to be covered in the frequency sweep. The operator also enters the desired voltage to be sent to the Dranetz. This manual voltage input is necessary since at higher frequencies lower rms voltages are necessary to keep the ac voltage meter on the Dranetz at 3.0 V.

Through the Data Acquisition Unit, the relative amplitude of the real part of the admittance is sampled at 300 equally spaced points throughout the selected frequency range. A graph is displayed on the CRT and then copied on the thermal printer of the HP-85 for later reference. In the event that some parameter needs to be changed, the operator is given the opportunity to rerun this portion.

The operator is instructed to specify a relative amplitude (from 0 to 1.2) that is less than the maximum of the admittance peak of interest. The computer prints the relative amplitudes greater than this value and the

associated frequencies. This allows the operator to select the resonance of interest and provide the center frequency and halfwidth to be considered in finding the resonant frequency and quality factor (Q). A comparison is done to find the absolute maximum value for amplitude and the half power points for the determination of Q. The resultant factors are printed and the option to rerun is again extended.

This same subroutine is again used to obtain similar data for the real part of the impedance. The subroutine is an adaptation of a part of a procedure designed by Conte [Ref. 13].

Although two repeats of the subroutine take about 10 minutes, the operator is given sufficient information on the impedance and the admittance responses of the transducer to decide which type of measurements will provide the most accurate information.

2. Data Collection

The computer has the frequency synthesizer send a frequency far below resonance. The meters of the Dranetz are zeroed by the operator and set for full scale deflection. An average of ten measurements for each

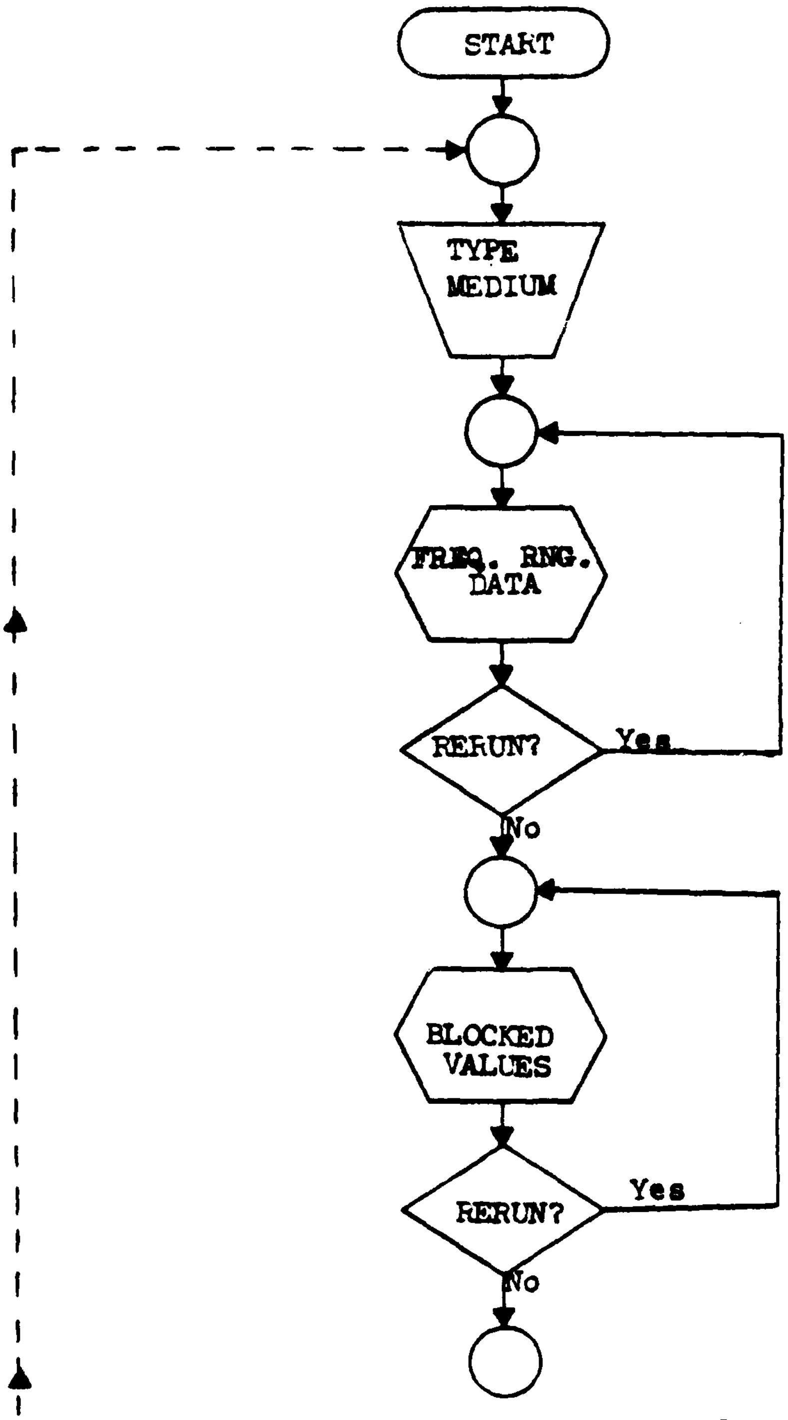


Figure 3.2 Flow Chart of the Program

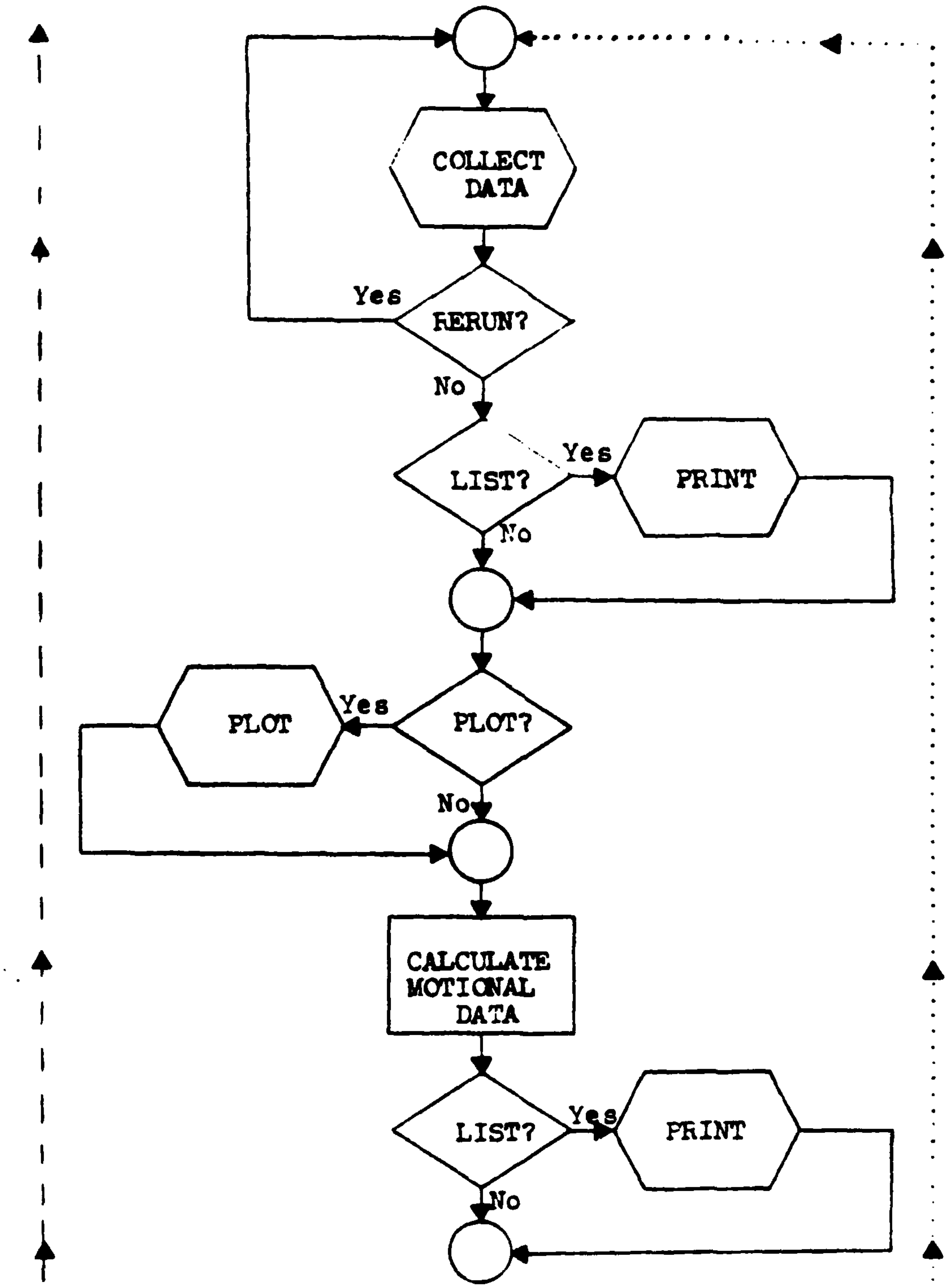


Figure 3.2 (Continued)

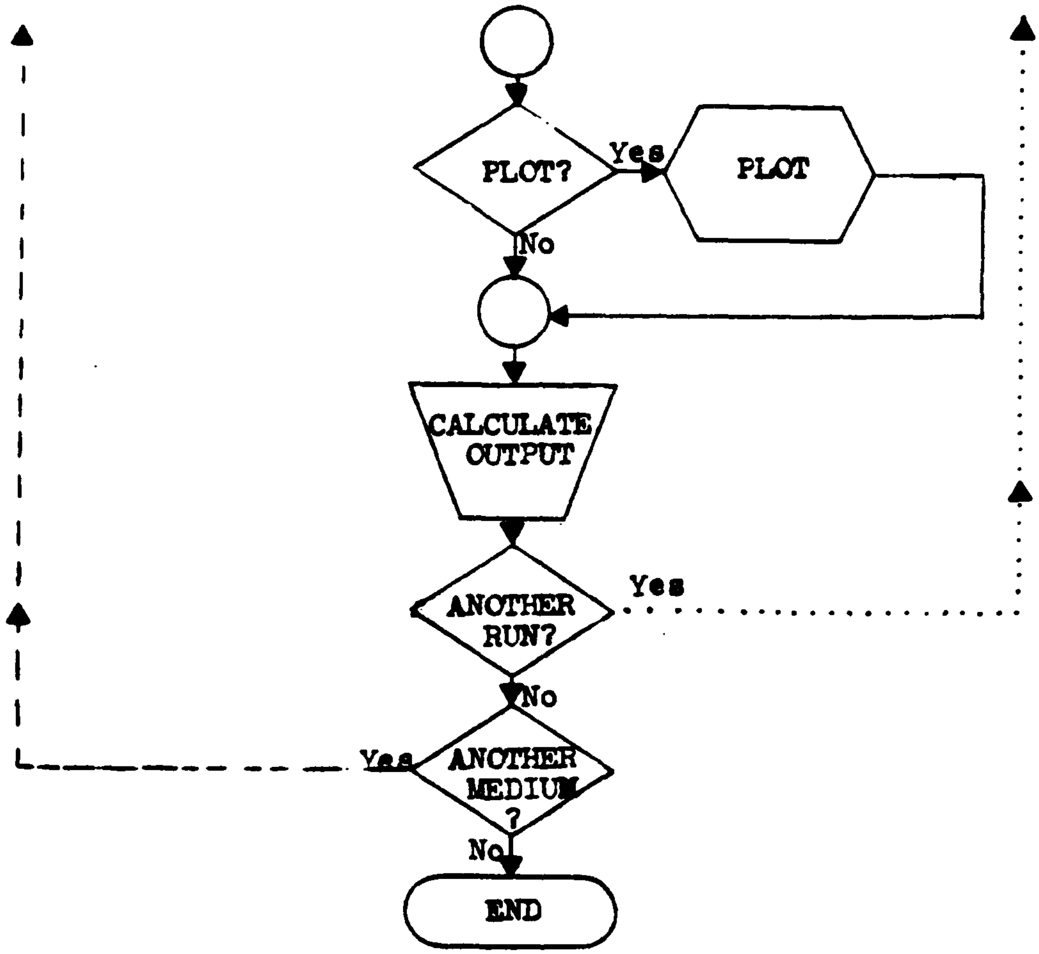


Figure 3.2 (Continued)

terminal is placed in memory to be used as normalization factors for all later DC output voltage measurements.

While still at this frequency far below resonance, an average of ten measurements will be made, normalized and scaled (using operator input for the scale factors from the Dranetz instrument) and stored as blocked values of conductance, susceptance, resistance and reactance. These will be used later in computations after being assigned to different variables depending on the medium. This one measurement is all that is necessary for the electrically coupled transducers with small dielectric losses. For the magnetically coupled transducers, the values are taken far below resonance and stored. The program loops back through this section after sending a message to the frequency synthesizer to go an equal frequency distance above resonance. An average of the two values is stored for later use. This averaging is necessary since the eddy current and hysteresis losses cause a steady increase in the blocked impedance values.

The decision of the operator on the type of data to be collected is entered. The scale factor from the Dranetz instrument is entered and the computer goes to a subroutine

for data collection. The computer draws the appropriate center frequency from the data collected during the search and bases the bandwidth for the sweep on the quality factor measured previously. Fifty frequencies and the associated real and imaginary data are measured and stored from ten times the half power bandwidth below center frequency to two times the bandwidth below resonance. Two hundred measurements are taken in the vicinity of resonance and another fifty in a region from two to ten times the bandwidth above resonance. (Note: This program reduces the range of interest to plus and minus five times the bandwidth around resonance when tests are done under load (water) conditions. The second program takes data at three hundred equally spaced frequencies within the bandwidth specified by the operator.) Once the data have been collected, another subroutine is entered to find the minimum and maximum values for the two sets of data and their associated frequencies. This is accomplished through a comparison to a minimum (or maximum) value until a smaller (larger) one is found. A reassignment is done and the comparison continues throughout the data. The maximum value and the two adjacent values are then fitted to a quadratic equation which is used to produce

a better estimate of the maximum and its associated frequency. In the event of an error in data collection, there is an opportunity to retake the data before proceeding in the program.

A subroutine provides for a listing of the collected data (100 points) in the vicinity of resonance. All of the data could be printed; however, the data near resonance provides the important information and printing is an option open to the operator.

Plots of the data may be made. The operator may chose to make plots of real or imaginary amplitudes versus frequency or the plots of real versus imaginary data over frequency, or all, or none. Each plot is drawn using a subroutine and labeled with pertinent scaling and captions. At the end of this chapter, Figures 3.3 through 3.14 are examples of plots for a piezoelectric transducer. (This example is for a Type 100-6363-010, Serial No. 1213, designed for use in an active sonobuoy.) Figures 3.15 through 3.22 are examples of plots for a magnetostrictive transducer. (This example is a Type CMT-10255, Model QGB, Serial No. 318.)

3. Data Manipulation

In the calculation of motional data, the type of coupling of the transducer becomes important.

a. Magnetic Coupling

For a magnetically coupled transducer, the motional impedance data is calculated by subtracting the blocked resistance from each resistance measurement. Blocked inductance at resonance is calculated using the averaged blocked reactance value. The angular frequency multiplied by the blocked inductance is then subtracted from each value of reactance. In the event admittance data has been collected, the motional conductance is obtained by subtracting the blocked conductance, while motional susceptance may be obtained by subtracting the blocked capacitance multiplied by the angular frequency from each value. A list of motional data may be obtained. A plot may be elected and drawn and labeled with axis scaling done using minimum and maximum values of the calculated data.

Computations are done using the collected data. The dynamic electromechanical coupling coefficient is calculated from the resonant frequencies. A new quality factor is calculated based on the frequencies of maximum and

minimum amplitudes of the imaginary part of the data collected. Values of some blocked measurements, quality factors, the coupling coefficient, and resonances are output to the printer.

b. Electric Coupling

For an electrically coupled transducer, dielectric losses are small and it is acceptible to use the values measured far below resonance as the blocked measurements. Motional resistance is obtained by subtracting the blocked resistance from each measurement. The addition of the angular frequency multiplied by the calculated blocked inductance to the reactance measurements will provide the motional reactance. The data may be listed and a plot made. An example of the motional impedance plot can be seen in Figure 3.9.

Motional admittance data may be obtained by subtracting the reciprocal of the blocked resistance from each conductance value. The angular frequency multiplied by the blocked capacitance is subtracted from each susceptance measurement. Figure 3.10 shows a motional admittance plot for a piezoelectric transducer in air. Calculations similar to those for magnetic coupling are done and desired values printed.

After measurements are taken with the transducer under load (in water) calculations are done to find the efficiency and optimal operating frequency (for magnetic coupling). This information is output to the printer. An opportunity to repeat data collection in either medium is afforded before data on air and water temperatures and transducer identification numbers are requested prior to the end of the program. A sample output (for the magnetostrictive transducer Type CMT-10255, Serial No. 318, Model QGB) is included as Figure 3.23.

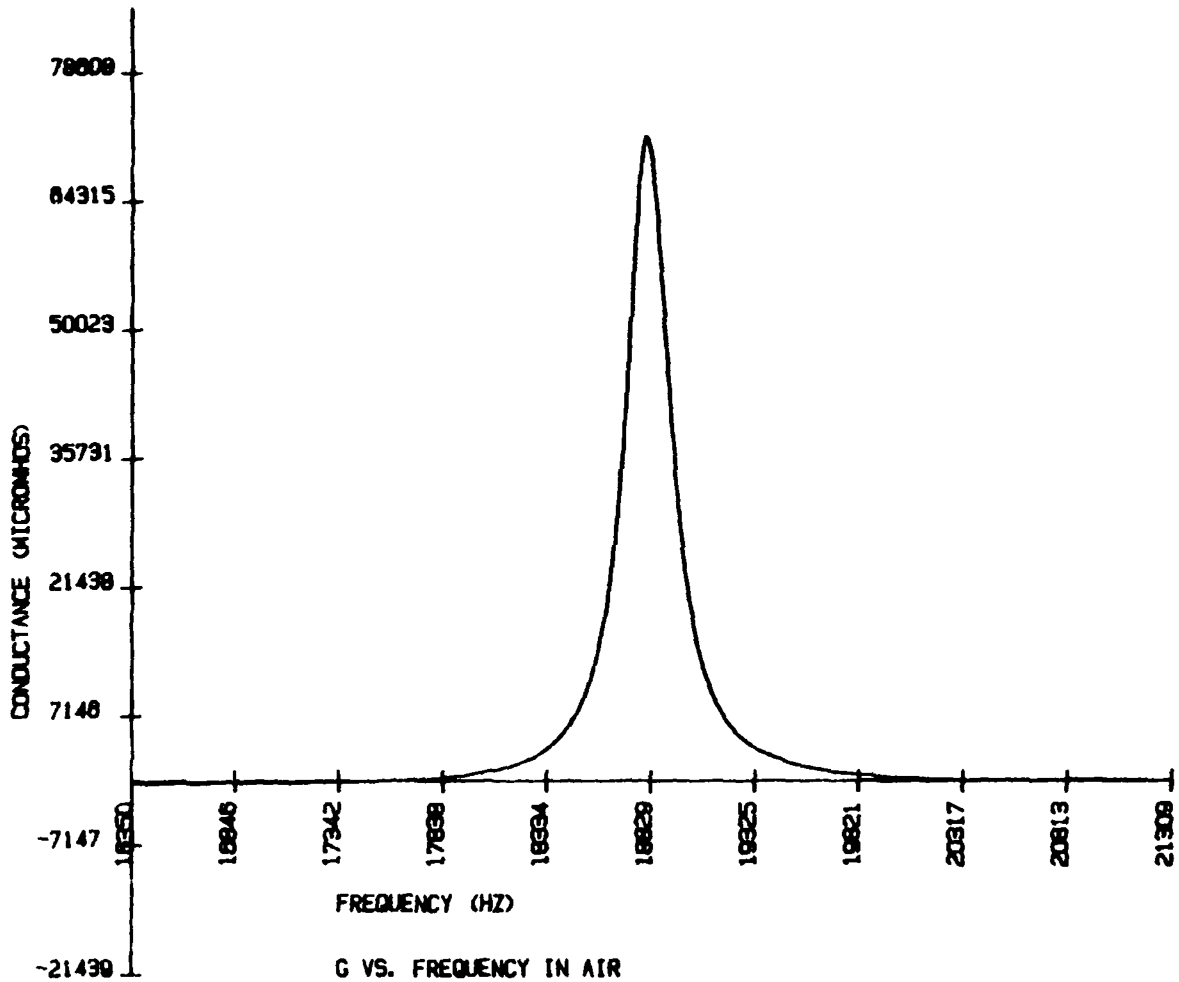


Figure 3.3 Conductance Spectrum for a Piezoelectric Transducer

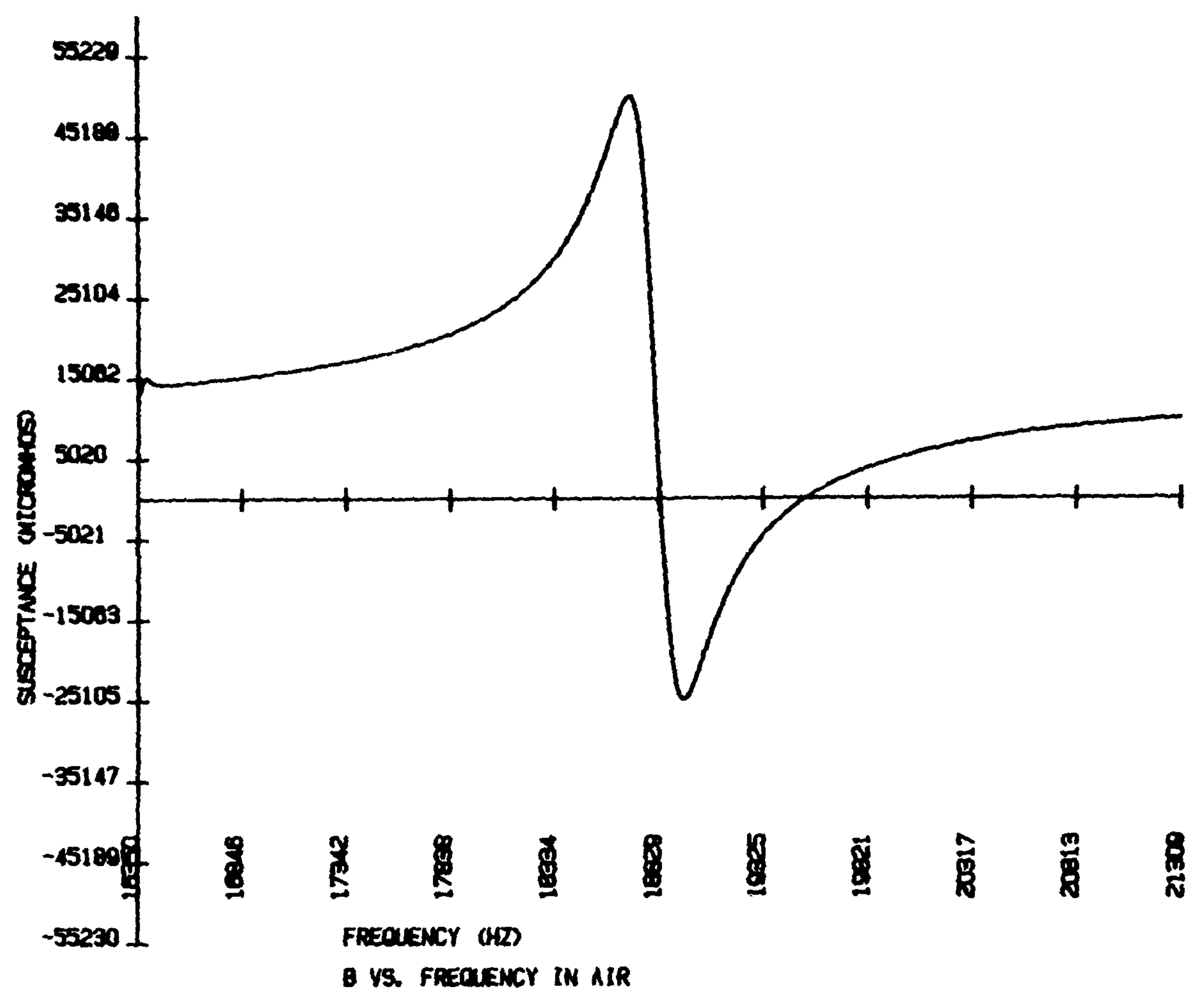


Figure 3.4 Susceptance Spectrum for a Piezoelectric Transducer

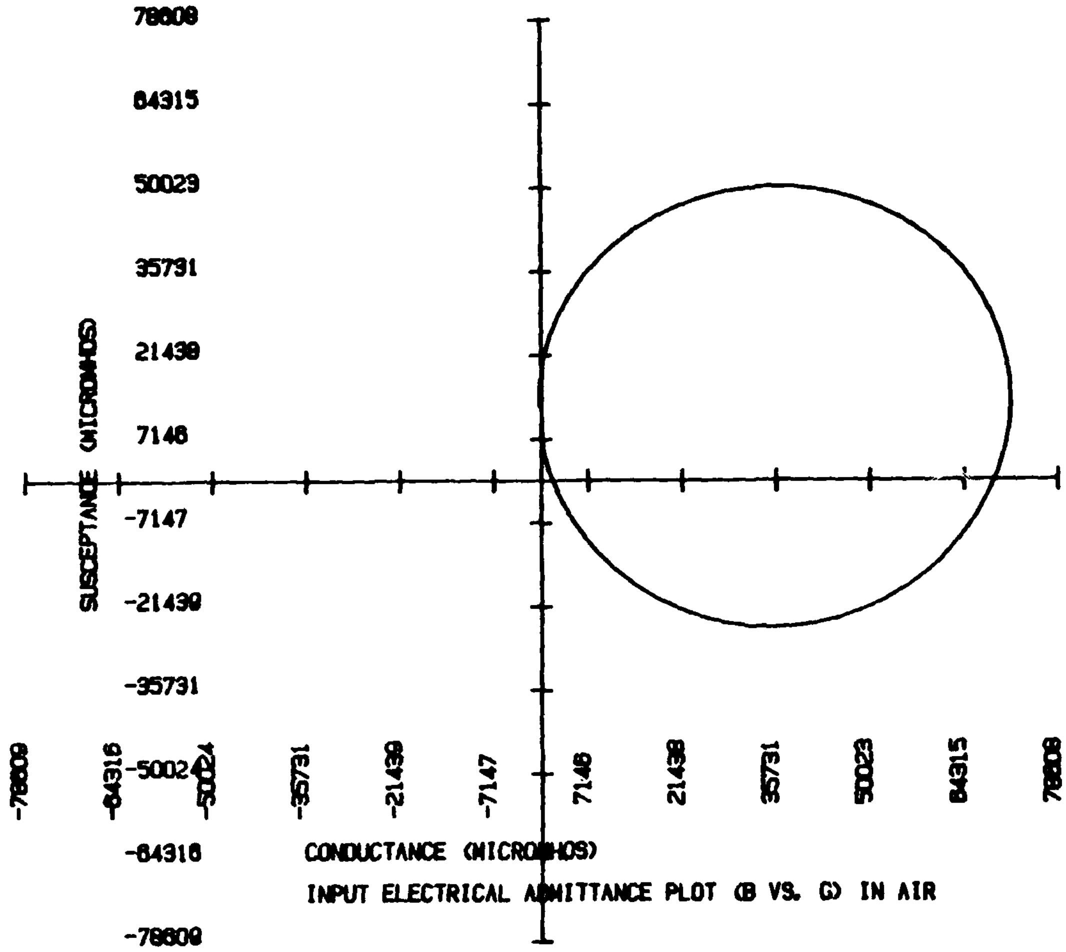


Figure 3.5 Input Electrical Admittance Plot for a Piezoelectric Transducer

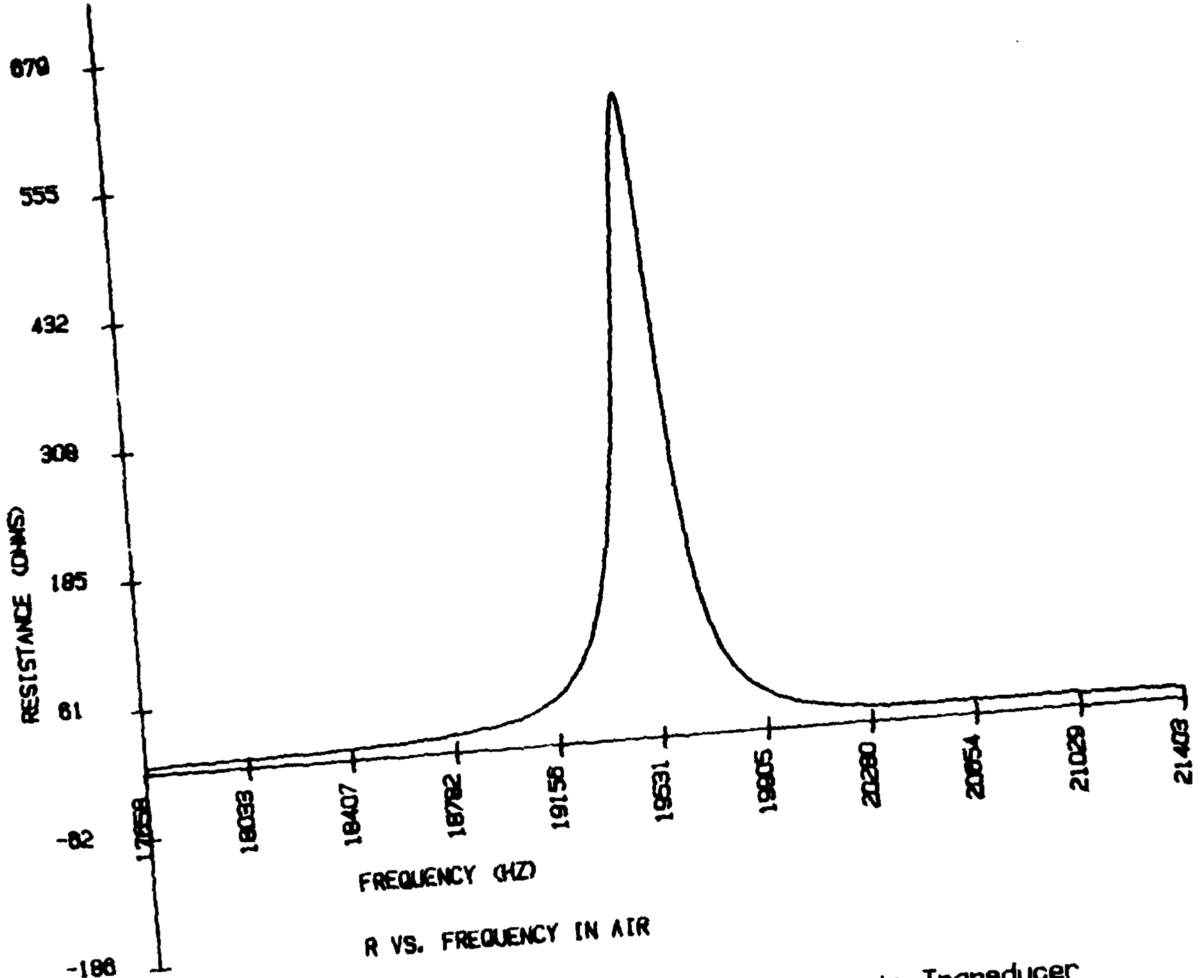


Figure 3.6 Resistance Spectrum for a Piezoelectric Transducer

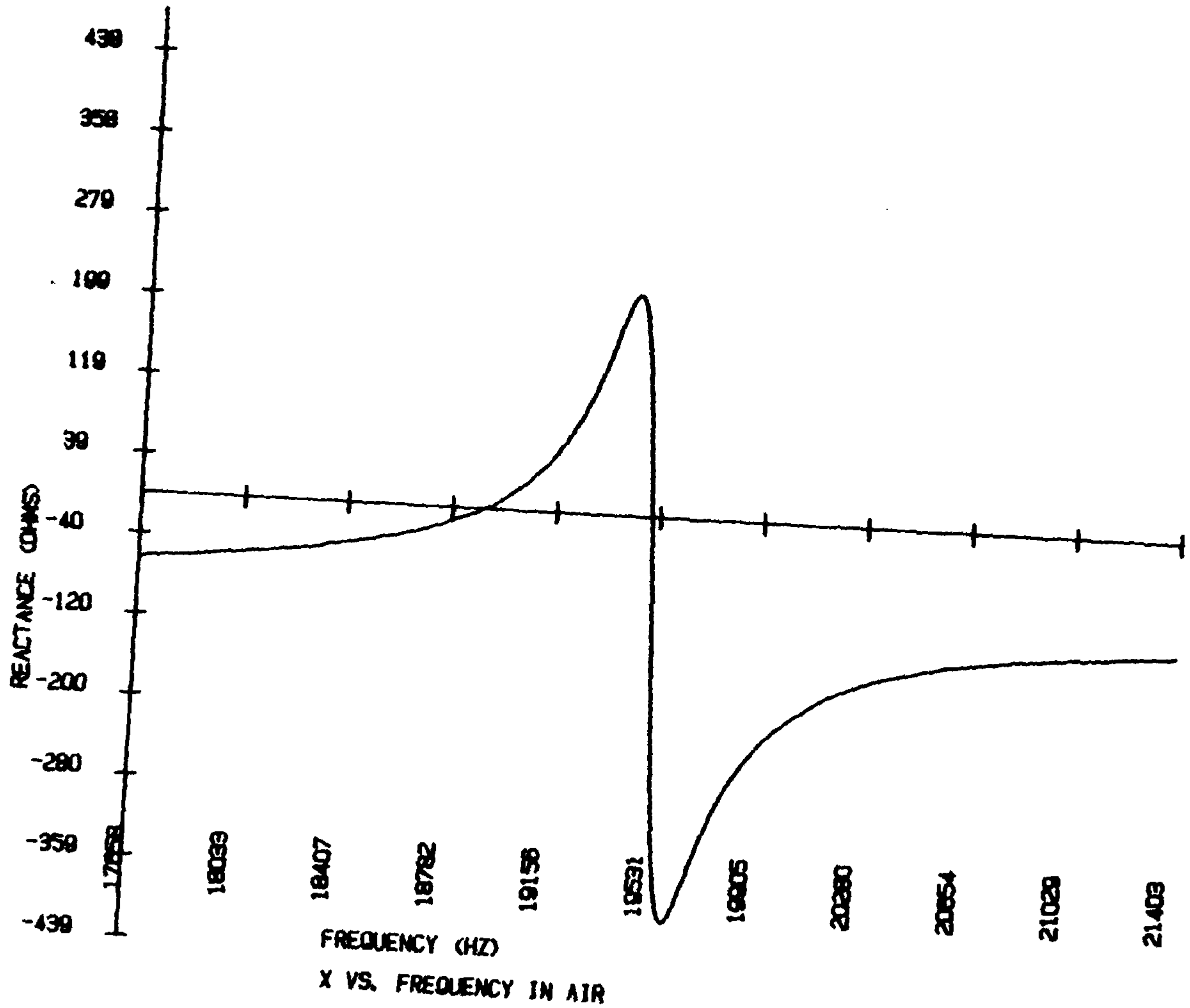


Figure 3.7 Reactance Spectrum for a Piezoelectric Transducer

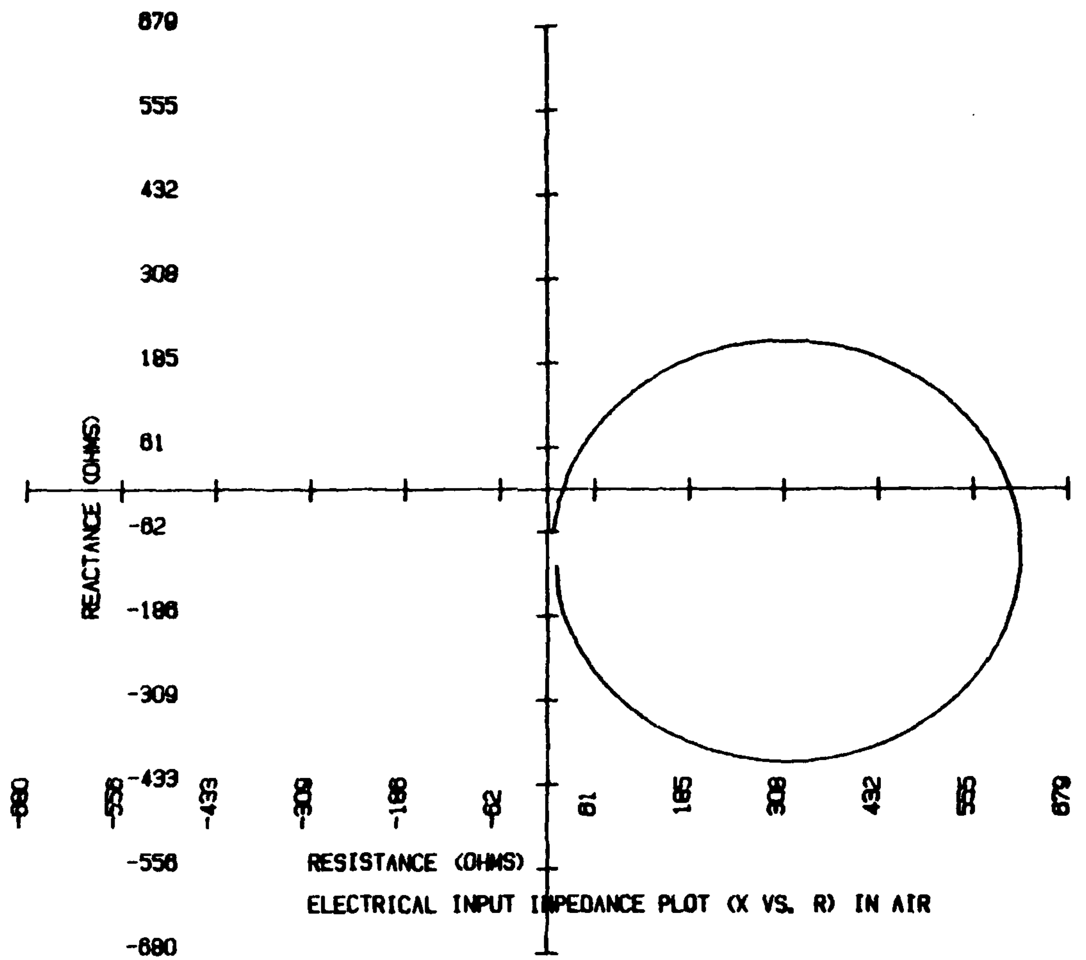


Figure 3.8 Electrical Input Impedance Plot for a Piezoelectric Transducer

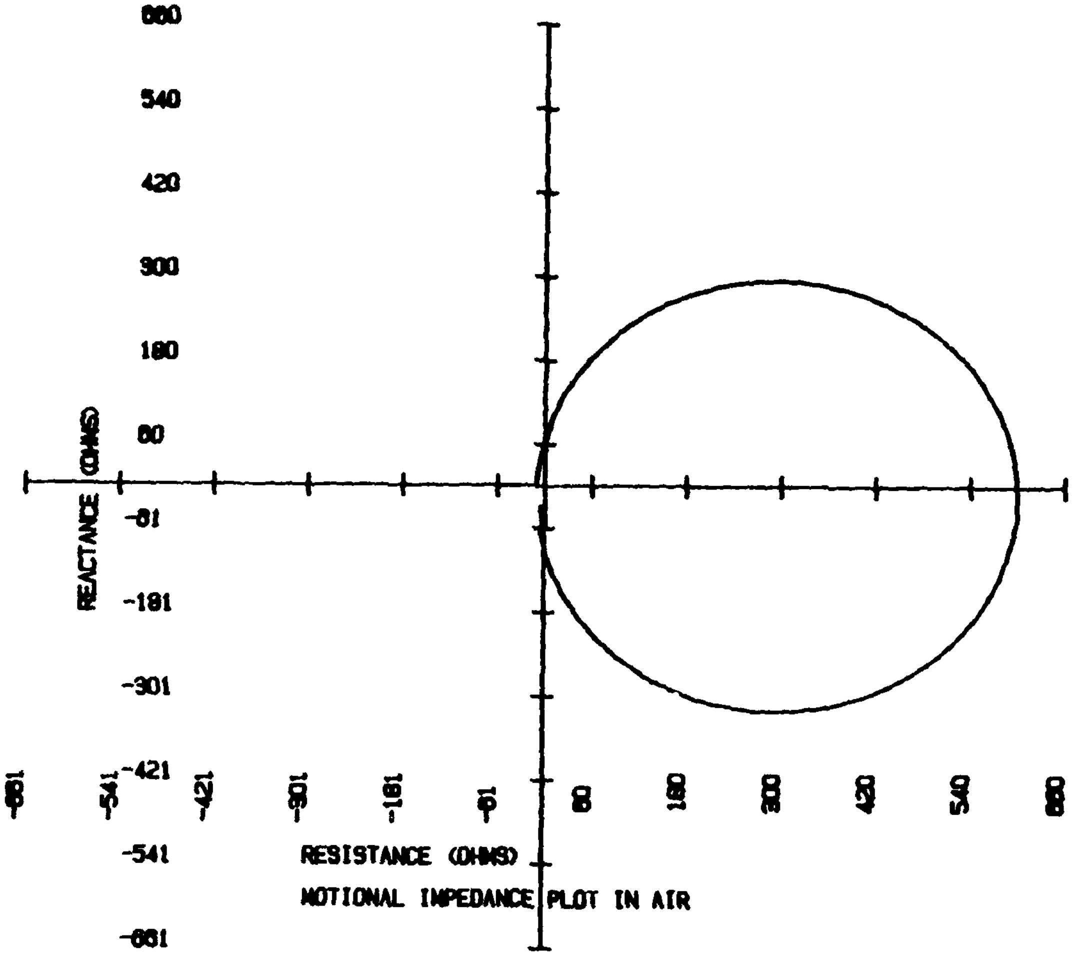


Figure 3.9 Motional Impedance Plot for a Piezoelectric Transducer

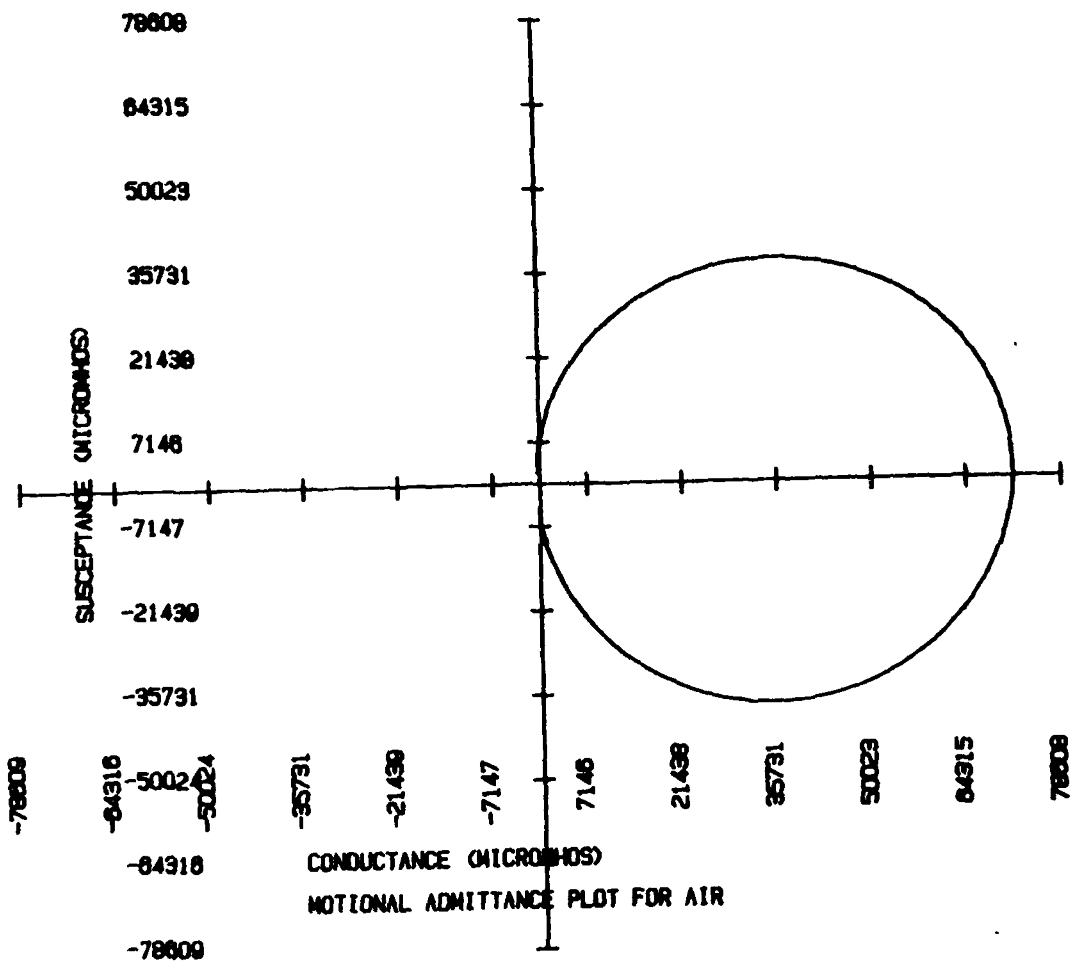


Figure 3.10 Motional Admittance Plot for a Piezoelectric Transducer

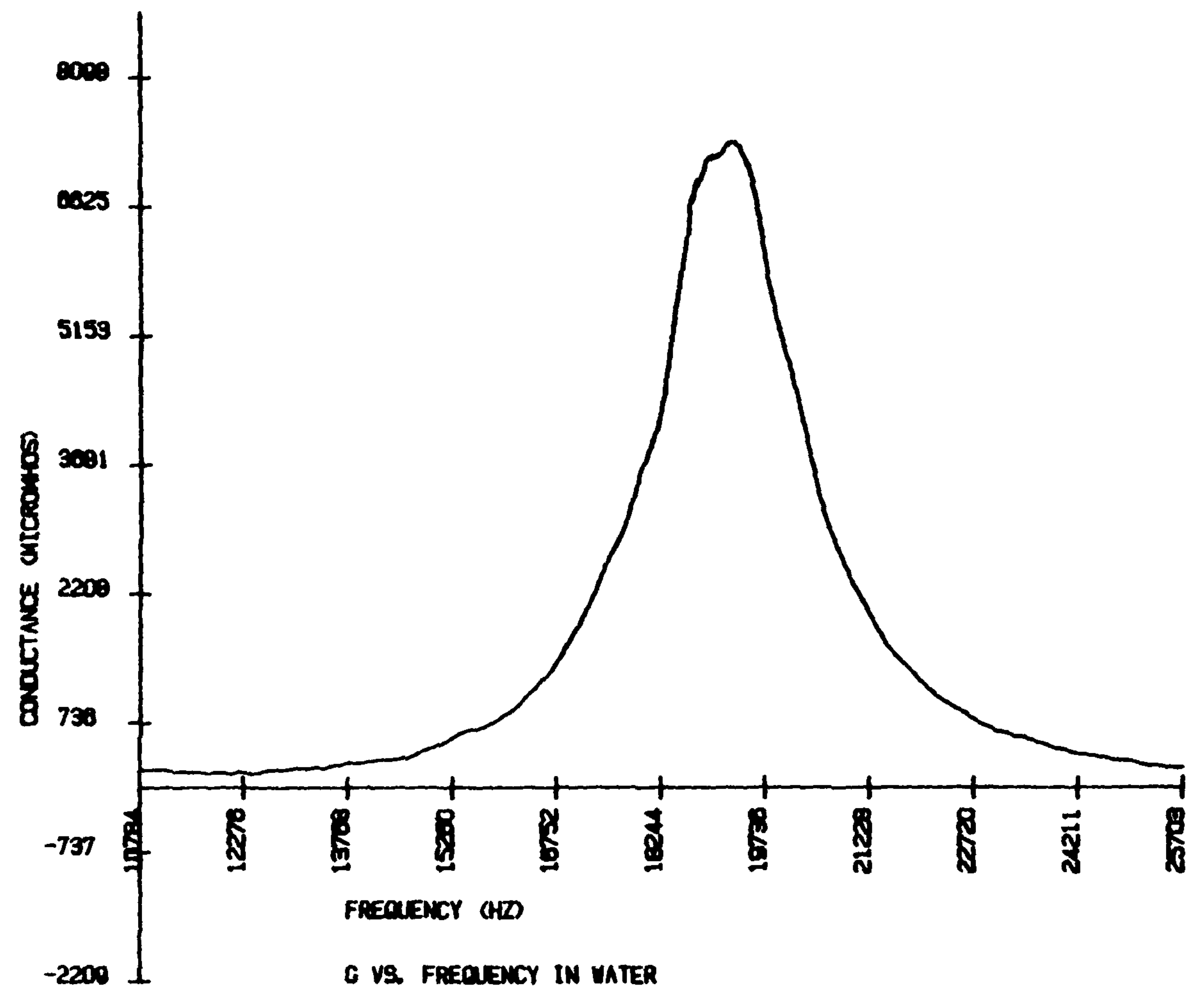
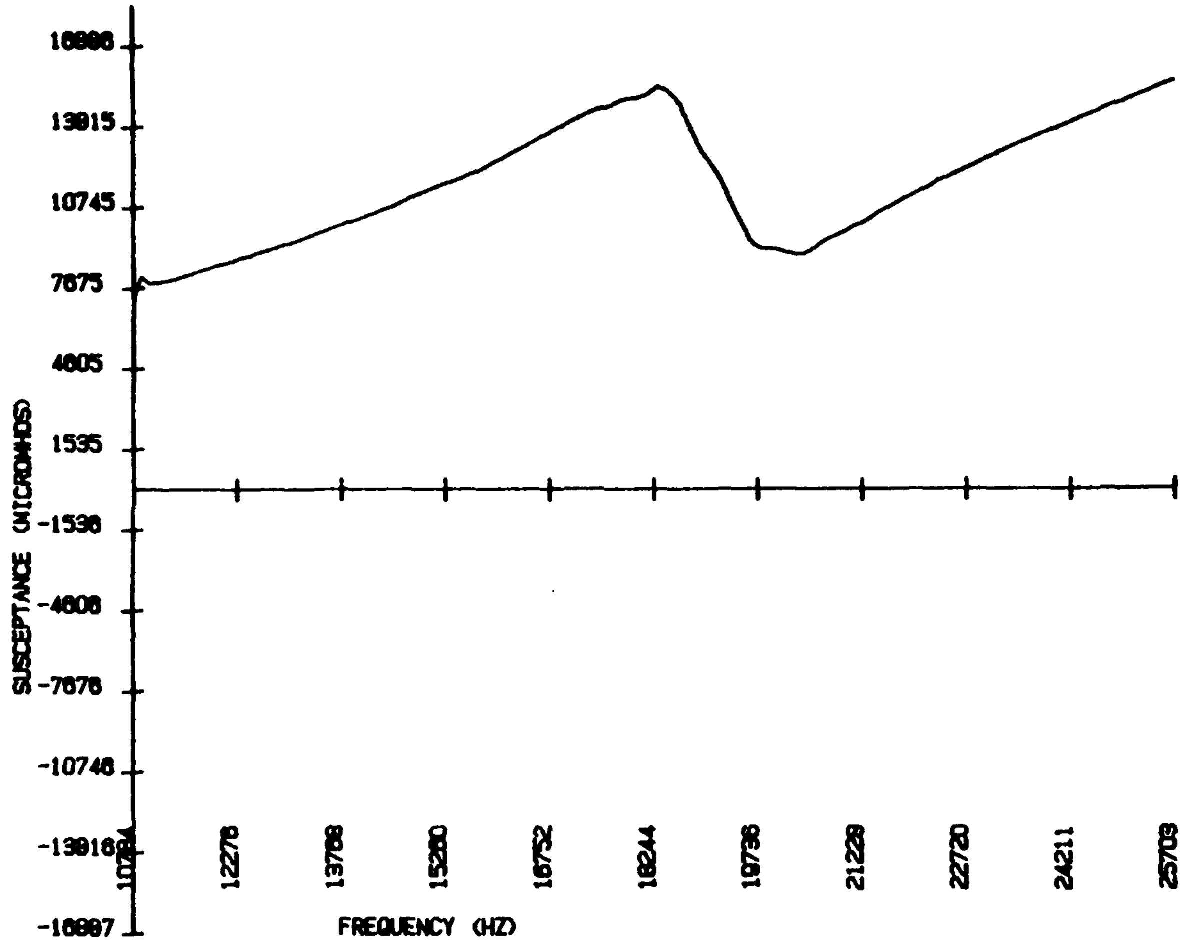


Figure 3.11 Conductance Spectrum for a Piezoelectric Transducer



B VS FREQUENCY IN WATER

Figure 3.12 Susceptance Spectrum for a Piezoelectric Transducer

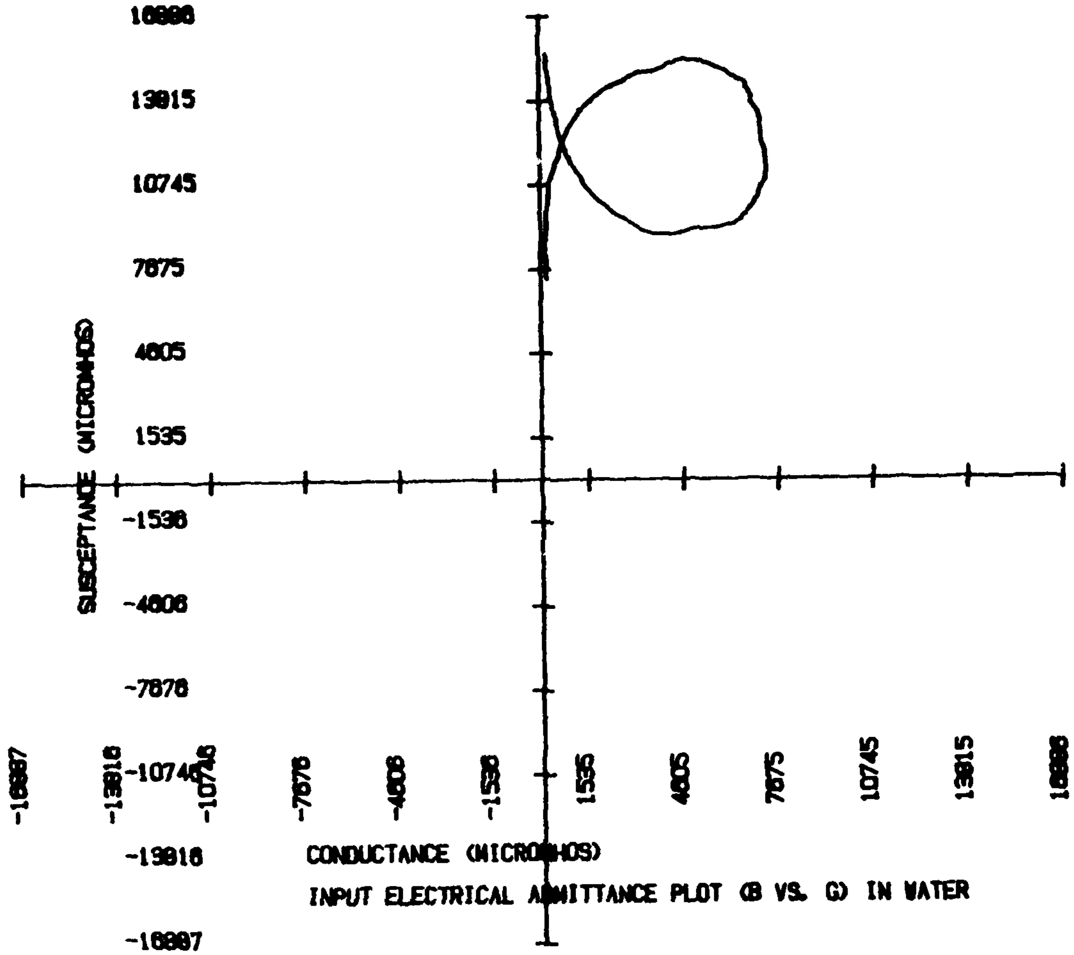


Figure 3.13 Input Electrical Admittance Plot for a Piezoelectric Transducer

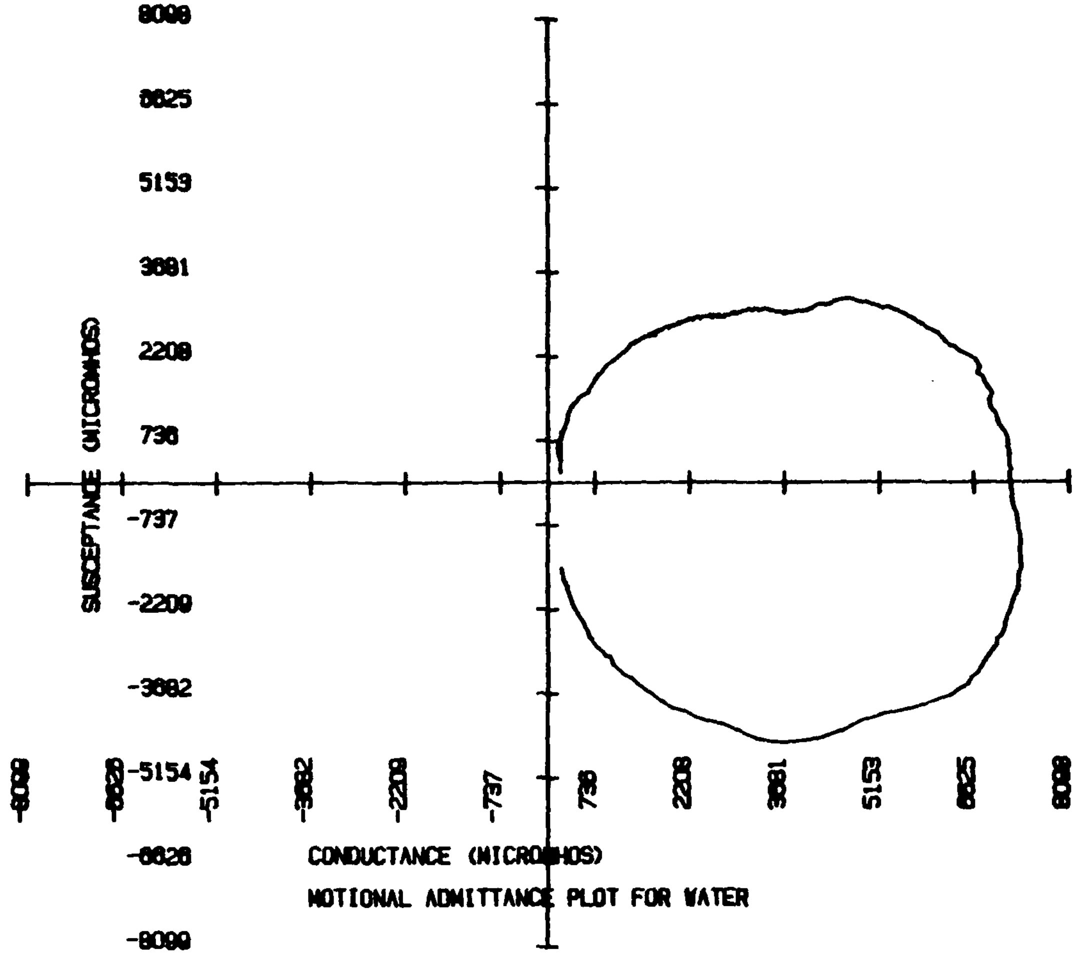


Figure 3.14 Motional Admittance Plot for a Piezoelectric Transducer

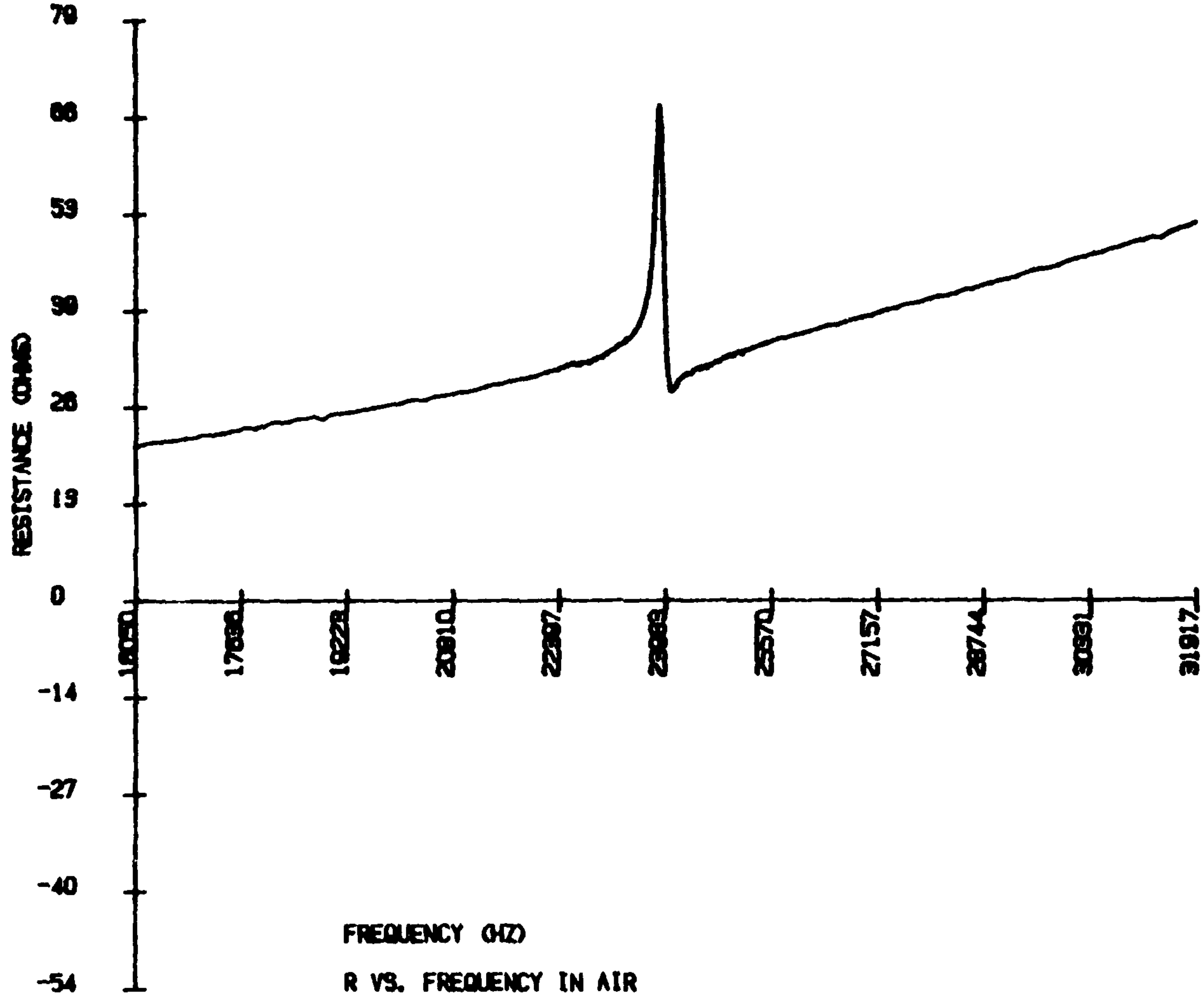


Figure 3.15 Resistance Spectrum for a Magnetostrictive Transducer

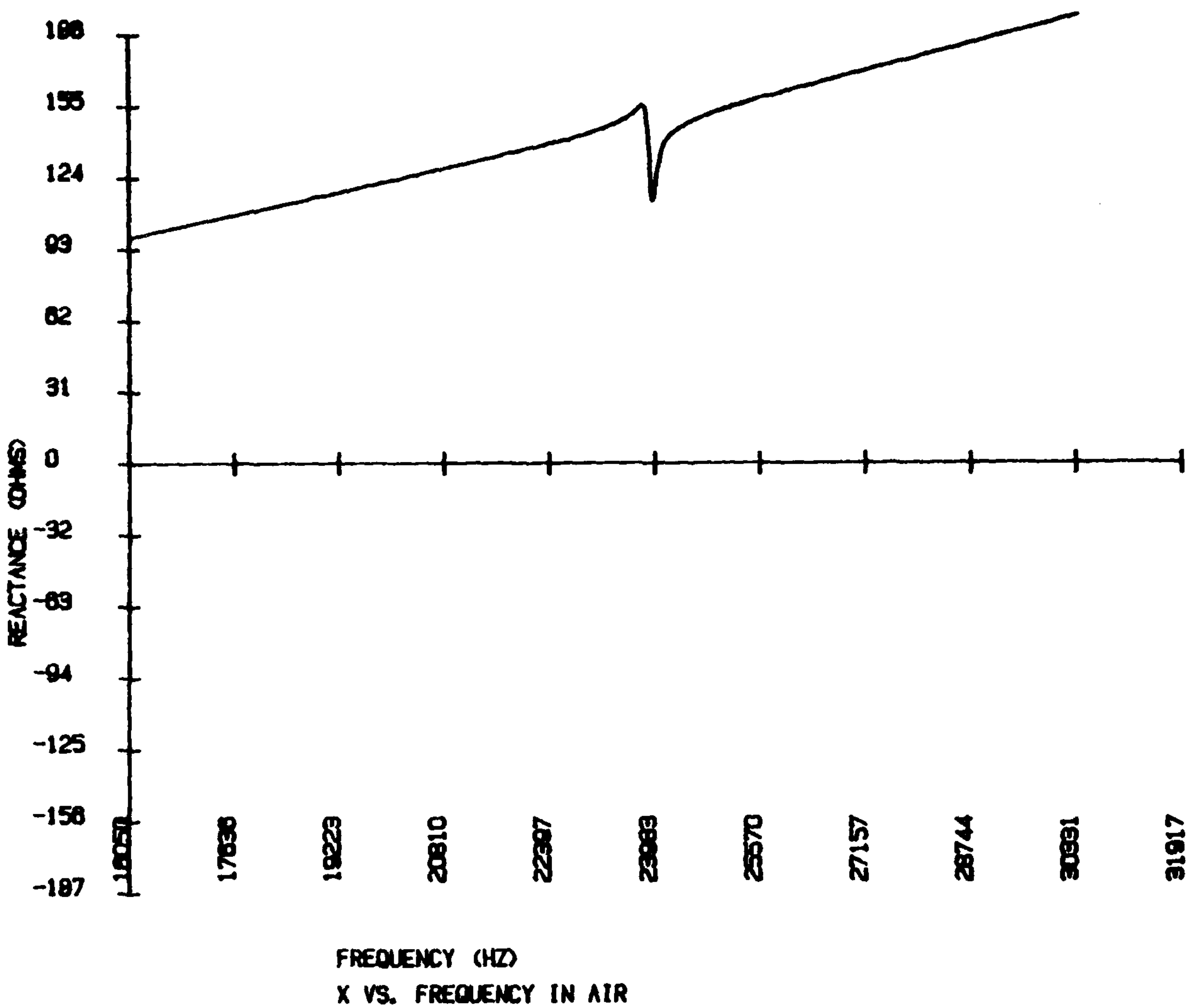
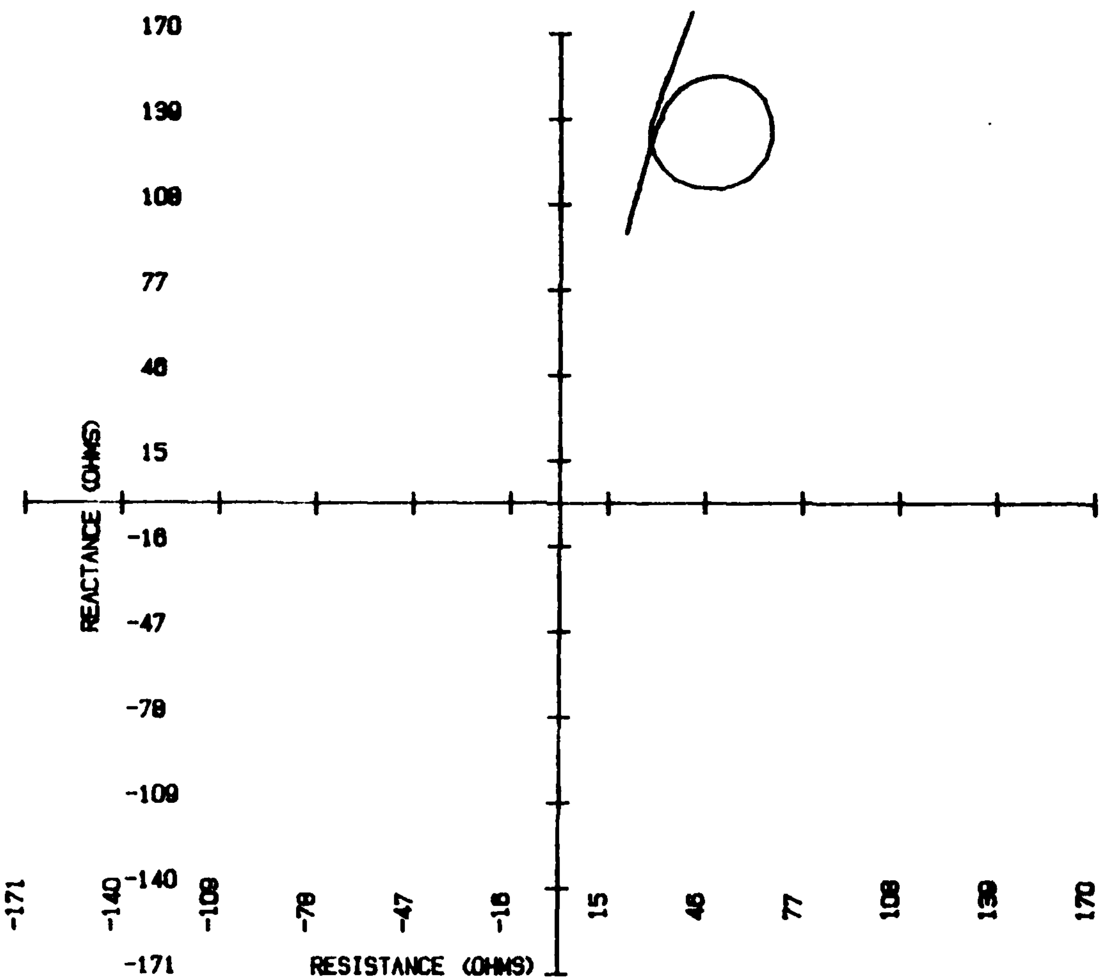


Figure 3.16 Reactance Spectrum for a Magnetostrictive Transducer



INPUT ELECTRICAL IMPEDANCE PLOT (XVS. R) IN AIR

Figure 3.17 Input Electrical Impedance Plot for a Magnetostrictive Transducer

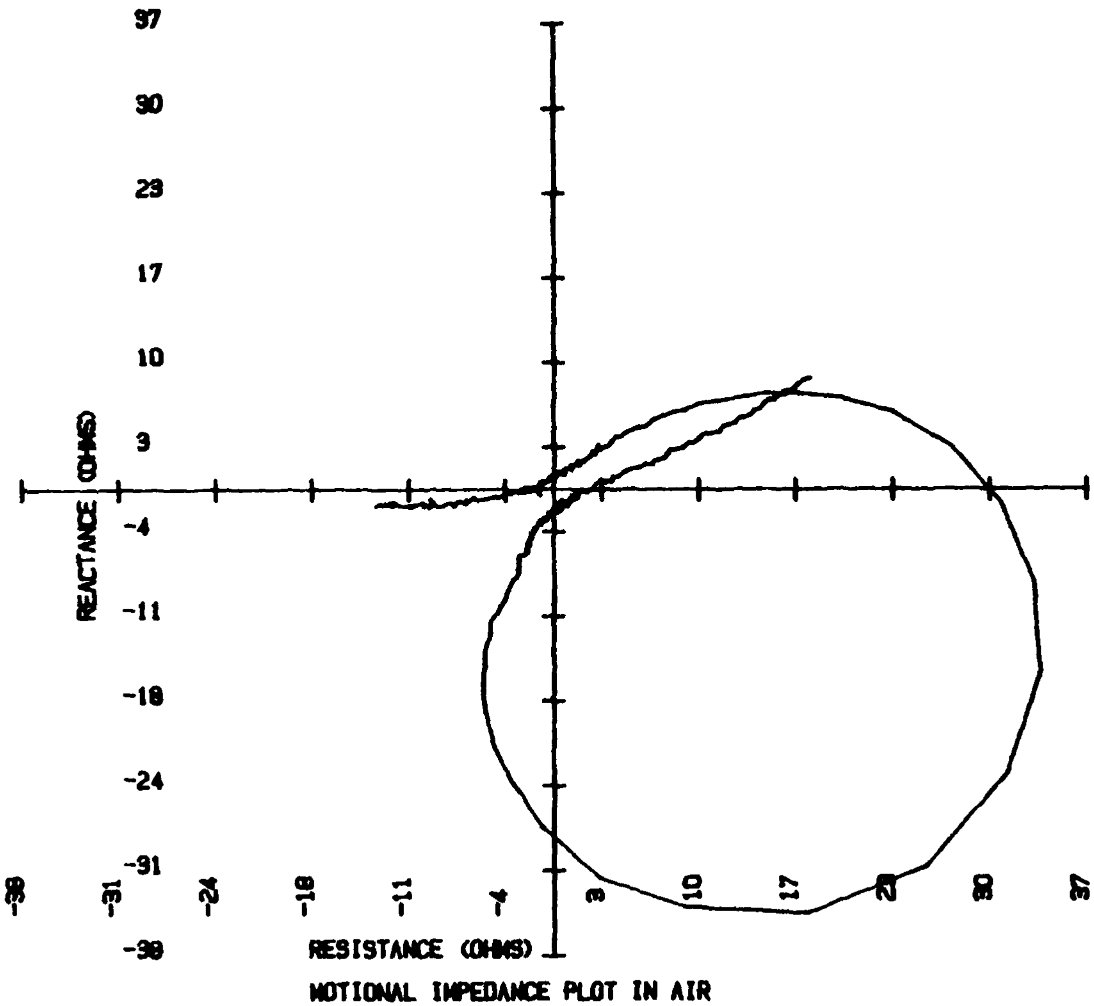


Figure 3.18 Motional Impedance Plot for a Magnetostrictive Transducer

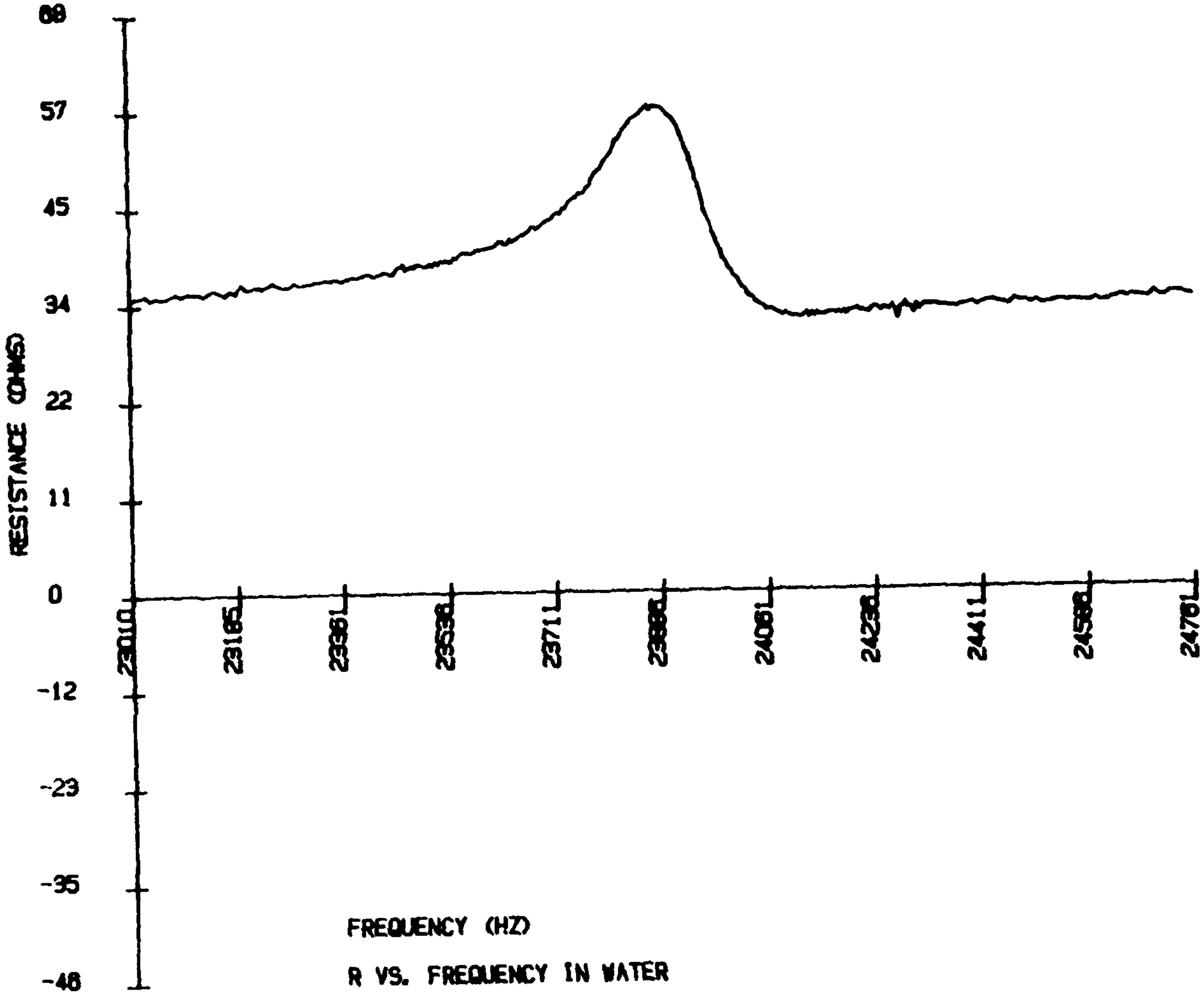


Figure 3.19 Resistance Spectrum for a Magnetostrictive Transducer

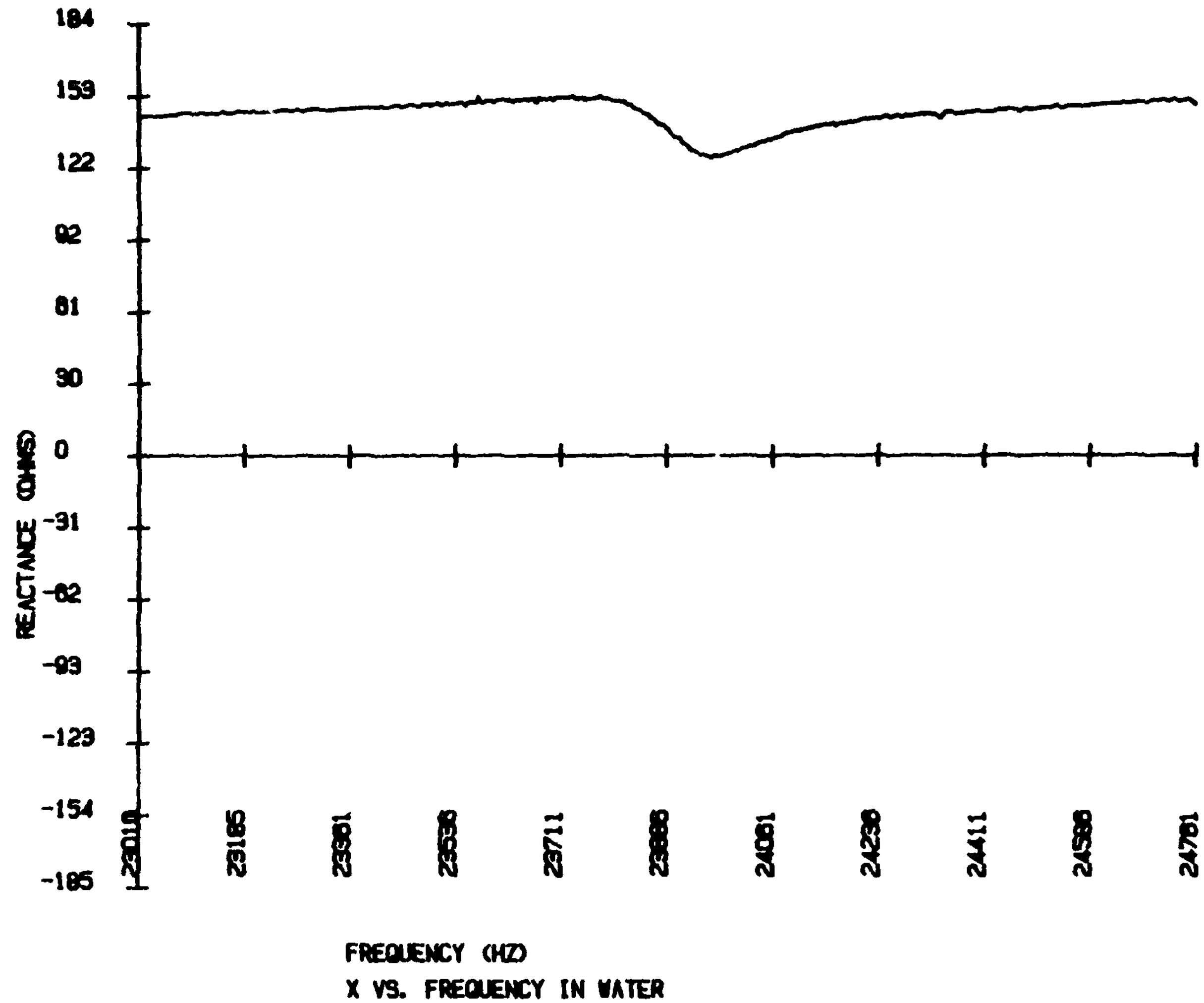


Figure 3.20 Reactance Spectrum for a Magnetostrictive Transducer

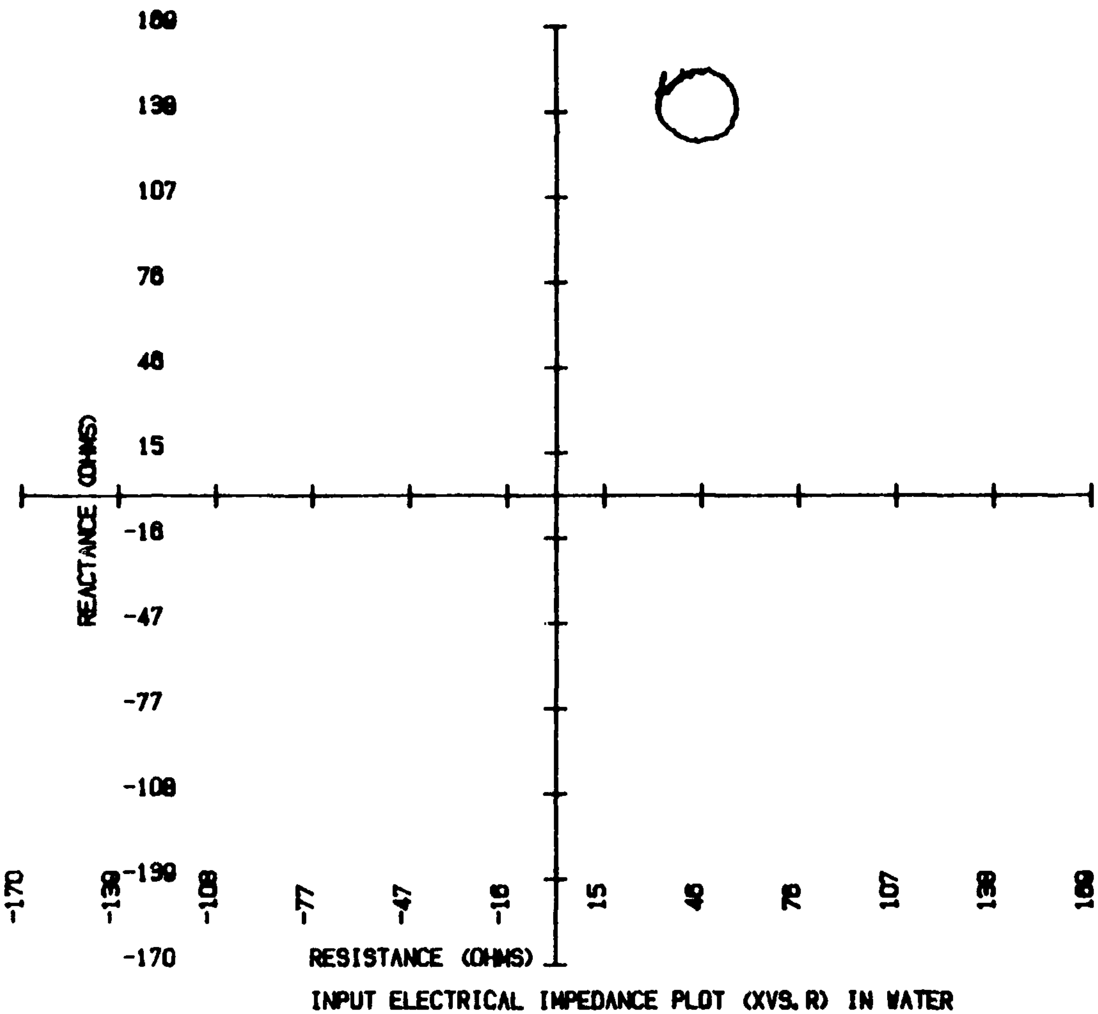


Figure 3.21 Input Electrical Impedance Plot for a Magnetostrictive Transducer

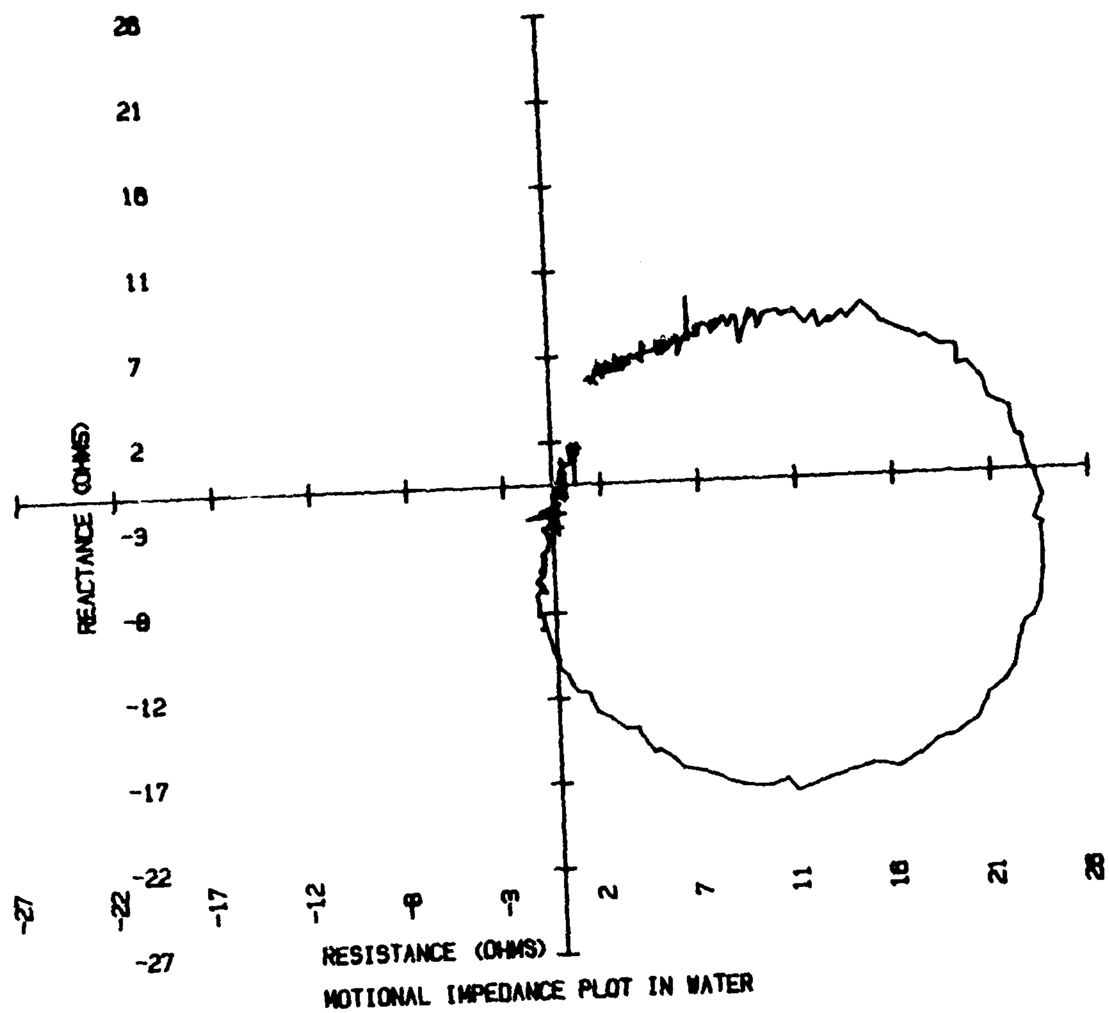


Figure 3.22 Motional Impedance Plot for a Magnetostrictive Transducer

VALUES MEASURED IN AIR FROM ADMITTANCE DATA

BLOCKED INDUCTANCE = 8.86E-4 HENRIES AT 23956 HZ
ELECTRICAL QUALITY FACTOR = 189.73
MECHANICAL QUALITY FACTOR = 29.426
ELECTRICAL RESONANCE = 23956.0379323 HZ
MECHANICAL RESONANCE = 23920 HZ
DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIENT = .003
BLOCKED RESISTANCE = 33.724 OHMS

VALUES FOR MEASUREMENTS IN WATER FROM ADMITTANCE DATA

BLOCKED INDUCTANCE = 9.01E-4 HENRIES AT 23932.48 HZ
ELECTRICAL QUALITY FACTOR = 18.513
MECHANICAL QUALITY FACTOR = 19.688
ELECTRICAL RESONANCE = 23932.4882297 HZ
MECHANICAL RESONANCE = 23892 HZ
DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIENT = .00338
POTENTIAL EFFICIENCY = .20398
FREQUENCY OF OPTIMUM EFFICIENCY = 24246.61 HZ
MECHANICAL POWER UTILIZATION FACTOR = .14645

Figure 3.23 Sample Computer Output

IV. TEST AND EVALUATION

Although many of the calculations made by the computer are basic, it was desireable to have a set of data collected manually to ensure accuracy of the semiautomated system.

A. TESTING

1. Method

Data were collected for four different transducers, all of which were later used to test the computerized system. A similar equipment set-up was used with the computer replaced by an operator and an X-Y plotter, and a Wavetek pulse/function generator in place of the synthesizer/function generator.

The frequency spectrum was swept manually with plots made of the real and imaginary components versus frequency. From these plots, amplitudes and frequency values were obtained and calculations similar to those done by the computer performed.

2. Comparisons

For the magnetostrictive transducer used here, the data output of the computer corresponds very closely to that collected manually. The blocked inductance was found to be

the same calculated by either method to five digits. Resonance frequency variations up to ten hertz may be attributed to temperature variations; and these frequency variations will affect the coupling coefficient. The efficiencies compared to within five percent.

Comparisons of the piezoelectric data were as favorable as that for the magnetostrictive transducer. The blocked capacitances varied by up to six percent and there were small resonance frequency differences in some cases.

B. EVALUATION

The resonance frequency variations noted may be attributed mainly to temperature changes from one experiment to another. Larger deviations noted in a few cases are due to inaccuracies in reading graphs or in determining a true maximum for a very low Q device as is the case for many transducers when placed under load. For the examples used here, the computer data are considered more accurate since it measures and compares data to five digits, far better than the average eye can do with unscaled data. In the computerized system, the data collected in the vicinity of resonance are compared to find the absolute maximum value and the associated frequency. This point and two adjacent

points are then used for a parabolic fit to find the precise frequency for maximum component amplitude. This provides accuracy in the resonance frequency far in excess of what may be achieved manually by an operator.

A 'delay time' to allow stablization of the system (dominated by the response time of the Dranetz meter) was determined to be one hundred milliseconds. In manually sweeping the frequency spectrum, stablization time is difficult to achieve. This may result in the appearance of spikes in the plots which increase the difficulty of manual evaluation of the collected data. Once this stablization time was determined, all wait times in the computer program were ensured to be greater than this value with the longest waiting period during determination of the shunt and normalization values. The second longest wait period occurs during the data collection. Here, a period of two hundred fifty milliseconds has been used in the vicinity of resonance to minimize the chance of error. The added minute for data collection that this additional wait time requires is of minor inconvenience compared to the improvement in accuracy.

Transducers may exhibit a moderately high Q in air (above 25). For these (and most resonances with a Q above 5) the program with set frequency ranges for data taking works well. However, these same transducers may have very low quality factors under load (in water). To avoid data review over a frequency range beyond the upper limits of the instruments and perhaps overlapping other resonances of the transducer, it is recommended that the program allowing for operator input of the frequency range be utilized.

C. CONCLUSIONS

It was noted that most transducers have more than one resonance. To be a useful analytical tool, the operator of this system needs to know the primary design frequency of operation for the test transducer. Should the resonance at this frequency cause the admittance or impedance to exceed the limits of the Dranetz meter, the operator may opt for data taking of the type to fall within limits.

Manual collection of impedance and admittance data for a single transducer in two media (air and water) and calculations similar to those done by the computerized system utilizing data at three hundred frequencies requires on the order of fifteen hours. This system carries out

these operations in seventy-four minutes. For most transducers, only one type of data (admittance or impedance) is normally collected. A typical measurement which produces results and the plots similar to Figures 3.15 through 3.23 would take fifty-two minutes. (Since each collection of data allows for four plots and two lists of data, the time to run the program collecting impedance and admittance data in both media could be reduced by forty minutes and collection of one type of data in both media by twenty minutes if no plots or lists were made and only the listing of transducer parameters similar to Figure 3.23 desired.)

The major time saving factor for this system would be found through the replacement of the Dranetz Impedance Meter with an instrument that does not require as much operator interface. However, semi-automation as provided in this system constitutes a major time-saving over manual means even when the equipment set-up is not altered in a major way.

The plots produced using an X-Y plotter and sweep oscillator enable measurements of frequency with an accuracy of about one percent. Using the computer, the precision is better than one in ten thousand. Similarly, for

calculations using real and imaginary components of the impedance or admittance, computer precision is better than one in ten thousand as opposed to about one in ten for manual manipulations. However, the measurement accuracy is at best plus or minus two percent for the Dranetz meter. The advantage gained over manual methods by using the computerized system is due to the systematic pauses for Dranetz meter stablization prior to all measurements.

This system has been designed to analyze any type of transducer. Specific adaptation to handle a particular transducer type with known resonance range can drastically reduce much of the operator interface necessary for evaluation of the properties of the transducer and reduce the time requirement accordingly. Adaptation for a particular type of transducer will allow variables currently in the computer program to be made constant. Careful selection of these values will maximize accuracy and precision in the desired measurements and calculations.

D. RECOMMENDATIONS FOR FURTHER IMPROVEMENTS

In all of the preceding discussions, it must be apparent that the "weak link" in this system is the Dranetz impedance meter which is over fifteen years old. The difficulties

with this device are primarily its lack of computer controllability, its plus or minus two percent accuracy, and its high noise at low signal levels.

Although it was unfortunately not available for this study, the Hewlett-Packard 4192A Low Frequency Impedance Analyzer seems to be the proper replacement for the Dranetz. It is capable of full program control via the HP-IB and would also eliminate the need for a separate frequency synthesizer and data acquisition system. It is highly recommended that this device be substituted in any future applications of this technique.

APPENDIX A

Two programs were written to implement the measurement procedures and the calculations to evaluate any type of transducer. The first program titled "HYDRA2" automatically looks at a frequency range of ten times the bandwidth on either side of the resonance frequency. (This is modified for water to be five times the bandwidth on either side.) This program also automatically selects the frequency at which to take shunt measurements based on the Q factors. The second program, titled "PICKBW", allows the operator to specify the bandwidth for analysis and the frequency at which to measure shunt values. The following reference guide is applicable for both programs. Major differences in the programs occur between lines 2501 and 2650 and between lines 8601 and 8635.

REFERENCE GUIDE

Line Nos.	Description
1 - 60	Declarations, inputs, "bookkeeping"
60 - 90	Admittance Spectrum (freq. & Q) using subroutine 7000
100-149	Impedance Spectrum (freq. & Q) using subroutine 7000
150	Obtains blocked values using subroutine 2501
153-176	Impedance data collection (option)
177-186	Admittance data collection (option)
198-450	Listing and plots of data using subroutines
451-500	Motional data calc. for magneto. (for 'Y' data)
525-540	Motional data calc. for elec. (for 'Y' data)
541-642	List of motional data and plot
645-657	Motional data calc. for elec. (for 'Z' data)
658-668	Motional data calc. for magneto. (for 'Z' data)
670-757	List of motional data and plot
800-940	Calculations for elec. coupling in air
1000-1031	Calculations for magn. coupling in air
1040-1146	Calculations for elec. coupling in water
1150-1225	Calculations for magn. coupling in water
1350-1410	Options for rerun or change of medium
2501-2650	Subroutine to determine blocked values
7000-7545	Subroutine for search and spectrum analysis
8100-8110	Subroutine to print data list
8200-8250	Subroutine to plot real data vs. freq.
8300-8380	Subroutine to plot imaginary data vs. freq.
8400-8450	Subroutine to plot 'circles'
8549-8573	Subroutine to obtain normalization factors

8600-8699	Subroutine to collect data
8700-8799	Subroutine to determine max/min values
9000-9350	Subroutines for printouts

```
1 REM **HYDRA2**
2 OPTION BASE 1
3 SHORT Q0,Q1,Q8,Q9,Q,E,E2,E3,E5,R8,R7,X2,X3,X5,X6,X7,X8
,G7,G8,B2,B3,B5,B6,B7,B8,K,K1,P5,P6,W
7 SHORT A,F2,F3,F4,F5,H3,H4,J1,J2,J3,J4,R,X,G,B
8 INTEGER M,Y,Y1,I,Y2,J,Z2,H1,H2,L2,S1
10 DIM B$[2],A$[2],T$[1],D(300,3),A1$[4],D$[300],L$[20],
R$[1],I$[1],S$[10],C$[5],G$[23],H$[23]
11 REAL S,N,N8,N9,R0,R9,X0,X9,L,C0,L0,O,P1,H8,H9,P,W0,G0
,G9,B0,B9,N(10),M(10),F0,F1,F6,F8,F9
14 REAL S8,E4,E6,L5,D,D1,D2,D3,D4
15 X6,D1,D2,D3,D4=0
16 Q,E2,E3,E5,R8,R7,X2,X3,X5=0
17 Z3,A,F2,F3,F4,F5,B6,B7,B8=0
18 S8,E4,E6,M,Y,Y1,I,Y2,J,Z2=0
19 K,K1,P5,P6,W,Q0,Q1,Q8,Q9,E=0
20 C0,L0,C,P1,E,H8,H9,P,W0,S=0
21 N,N8,N9,R0,R9,X0,X9,G0,G9=0
22 B0,B9,H1,H2,F0,F1,F6,F8,F9=0
25 DISP "THIS PROGRAM AUTOMATICALLY SELECTS HALFWIDTH FO
R DATA COLLECTION."
26 DISP "THIS LOOKS AT 10 X BW IN AIR & 5 X BW IN WATER.
"
27 DISP "TO INPUT YOUR OWN BANDWIDTH USE ''PICKBW'' PROGRA
M INSTEAD.(HIT ''CONT'')"
29 PAUSE
30 CLEAR @ BEEP
35 DISP "ENTER TYPE OF TRANSDUCER TO BE MEASURED?(''M'' FO
R MAGNETIC COUPLING OR ''E'' FOR ELEC.)"
42 INPUT T$@ DISP "TO GET A COMPLETE SET OF DATA YOU NEE
D MEASUREMENTS IN BOTH AIR AND WATER. "
45 DISP "DO AIR FIRST.IN WHAT MEDIUM ARE YOU OPERATING?(
ENTER ''1'' FOR AIR OR ''2'' FOR WATER)"
46 INPUT M@ CLEAR @ BEEP
47 IF M=2 THEN 49
48 C$="AIR" @ Z2=10 @ GOTO 51
49 C$="WATER" @ Z2=5
51 PRINTER IS 2 @ PLOTTER IS 1
55 DISP "SET THE DRANETZ FOR ADMITTANCE.SET ON LOWEST SC
ALE THAT WON'T PEAK DURING RUN.(CONT)"
60 PAUSE
65 PRINT @ PRINT @ PRINT
70 PRINT "ADMITTANCE IN ";C$
75 GOSUB 7000
80 IF M=2 THEN 90
85 F0=F6 @ Q0=Q @ GOTO 100
90 F1=F6 @ Q1=Q
100 GCLEAR @ CLEAR @ BEEP
105 DISP "SET DRANETZ FOR IMPEDANCE-(SCALE NEEDED)-HIT C
ONT "
```

```
110 PAUSE
115 PRINT @ PRINT @ PRINT
120 PRINT "IMPEDANCE IN ";C$
125 GOSUB 7000
130 IF M=2 THEN 140
135 F8=F6 @ Q8=Q @ GOTO 141
140 F9=F6 @ Q9=Q
141 CLEAR @ BEEP
142 PRINTER IS 701,76 @ PRINT USING 144
144 IMAGE 2/
145 PRINT "F(Y-AIR)= ";INT(F0),,"F(Y-WAT)= ";INT(F1),,"F
(Z-AIR)= ";INT(F8),,"F(Z-WAT)=";INT(F9)
146 PRINT "Q(Y-AIR)= ";Q0,,"Q(Y-WATER)= ";Q1,,"Q(Z-AIR)=
 ";Q8,,"Q(Z-WATER)= ";Q9
147 PRINTER IS 2
148 CLEAR @ DISP "THESE ARE THE INITIAL ESTIMATES.(HIT ''
CONT' WHEN READY TO PROCEED)"
149 PAUSE
150 GOSUB 2501
152 CLEAR @ BEEP
153 DISP "TO COLLECT ADMITTANCE DATA (FOR ELEC. COUPLING
) ENTER '1'. ENTER '2' FOR IMPEDANCE"
154 INPUT L2@ PRINTER IS 2
155 IF L2=2 THEN 158
156 R$="G" @ I$="B" @ S$="ADMITTANCE" @ H$="CONDUCTANCE
(MICROMHOS)" @ G$="SUSCEPTANCE (MICROMHOS)"
157 GOTO 159
158 R$="R" @ I$="X" @ S$="IMPEDANCE" @ G$="REACTANCE (OH
MS)" @ H$="RESISTANCE (OHMS)"
159 IF L2=1 THEN 176
160 CLEAR @ DISP "SET ON Z AND ENTER SCALE FACTOR TO COL
LECT DATA."
161 INPUT S8@ PRINT S$;" IN ";C$ @ PRINT "SCALE =";S8;"
OHMS"
162 CLEAR @ DISP "I AM WORKING"
164 GOSUB 8600
165 IF Y=2 THEN 152
166 IF M=2 THEN 169
167 R6=E @ X3=E2 @ X8=E3 @ F4=E4
168 X6=E5 @ F5=E6 @ F8=E1 @ GOTO 198
169 R7=E @ X2=E2 @ X7=E3 @ F4=E4
170 X5=E5 @ F5=E6 @ F9=E1 @ GOTO 198
176 CLEAR @ BEEP
177 DISP "SET ON Y & ENTER SCALE FACTOR IN MICROMHOS TO
COLLECT DATA."
178 INPUT S8@ PRINT S$;" IN ";C$ @ PRINT "SCALE =";S8;"
MICROMHOS"
179 GOSUB 8600
180 IF Y=2 THEN 152
181 IF M=2 THEN 185
```

```
182 G8=E @ B3=E2 @ E8=E3 @ F2=E4
183 B6=E5 @ F3=E6 @ F0=E1 @ GOTO 198
185 G7=E @ B2=E2 @ B7=E3
186 F2=E4 @ B5=E5 @ F3=E6 @ F1=E1
196 PRINT USING 199
199 IMAGE 2/
200 DISP "DO YOU DESIRE A LIST OF COLLECTED DATA NEAR RE
SONANCE? (100 POINTS)(1=YES,2=NO)"
201 INPUT Y
202 IF Y=2 THEN 300
204 IF L2=2 THEN 240
210 PRINT "ADMITTANCE DATA FOR ";C$;" IN MICROMHOS" @ PR
INT USING 215
215 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
216 GOTO 265
240 PRINT "IMPEDANCE DATA FOR ";C$;" IN OHMS" @ PRINT US
ING 215
265 GOSUB 8100
300 CLEAR @ DISP "DO YOU DESIRE A PLOT OF DATA?(1=YES,2=
NO)"
305 INPUT Y@ GCLEAR @ CLEAR
315 IF Y=2 THEN 450
320 DISP "ENTER: 1= G/R VS. FREQ; 2= B/X VS. FREQ; 3= B
VS. G/X VS. R; 4= END PLOTTING LOOP."
325 INPUT Y
330 IF Y=2 THEN 385
335 IF Y=3 THEN 425
340 IF Y=4 THEN 450
345 GOSUB 8200
356 LDIR 0 @ PEN 1 @ PENUP
357 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-(E*.8)
360 LABEL R$;" VS. FREQUENCY IN ";C$
361 GOTO 320
385 GOSUB 8300
397 LDIR 0 @ PEN 1 @ PENUP
398 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-L-.5*L
400 LABEL I$;" VS. FREQUENCY IN ";C$
401 GOTO 320
425 GCLEAR @ CLEAR @ GOSUB 8400
431 PEN 1
442 LDIR 0 @ PENUP
443 MOVE -(.5*L),-L-.2*L
445 LABEL "INPUT ELECTRICAL ";S$;" PLOT (";I$;"VS.";R$;"
) IN ";C$
446 GOTO 320
450 IF L2=2 THEN 645
451 IF T$="E" THEN 525
452 GCLEAR @ CLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
465 C0=B*.000001/(2*PI*F6)
```

```
466 L0=1/((2*PI*F6)^2*C0)
470 FOR I=1 TO 300
475 D(I,2)=D(I,2).-G
480 D(I,3)=D(I,3).-D(I,1)*B/F6
485 NEXT I
490 GOSUB 8700
500 GOTO 541
525 GCLEAR @ CLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
532 C0=B*.000001/(2*PI*F)
535 FOR I=1 TO 300
536 D(I,2)=D(I,2).-G
537 D(I,3)=D(I,3).-D(I,1)*B/F
538 NEXT I
540 GOSUB 8700
541 CLEAR @ GCLEAR @ BEEP
542 DISP "DO YOU DESIRE A LIST OF MOTIONAL DATA NEAR RES
ONANCE?(1=YES, 2=NO)"
543 INPUT Y
545 IF Y=2 THEN 604
575 PRINT "MOTIONAL ADMITTANCE DATA IN ";C$ @ PRINT USIN
G 580
580 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
595 GCLEAR @ CLEAR
600 GOSUB 8100
604 CLEAR @ BEEP @ BEEP
605 DISP "WANT A PLOT?(1=YES,2=NO)"
610 INPUT Y2
615 IF Y2=2 THEN 755
616 PLOTTER IS 705 @ PEN 1
620 GOSUB 8400
628 LDIR 0 @ PENUP @ PEN 1
629 MOVE -(.5*L),-L-.2*L
630 LABEL "MOTIONAL ";S$;" PLOT FOR ";C$
642 GOTO 755
645 CLEAR @ GCLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
646 IF T$="M" THEN 658
647 FOR I=1 TO 300
648 D(I,2)=D(I,2)-R
649 C0=1/(2*PI*F*X)
650 L0=1/((2*PI*F6)^2*C0)
651 D(I,3)=D(I,3).-2*PI*D(I,1)*L0
652 NEXT I
653 GOSUB 8700
654 C0=ABS(C0) @ L0=ABS(L0) @ BEEP
655 DISP "DO YOU WANT A LIST OF THE DATA NEAR RESONANCE?
(1=YES,2=NO)"
656 INPUT Y
657 GOTO 670
```

```
658 L0=X/(2*PI*F6)
662 FOR I=1 TO 300
663 D(I,2)=D(I,2)-R
664 D(I,3)=D(I,3)-D(I,1)*2*PI*L0
665 NEXT I
666 GOSUB 8700
667 BEEP @ DISP " DO YOU WANT A LIST OF DATA NEAR RESONA
NCE?(1=YES,2=NO)"
668 INPUT Y
670 IF Y=2 THEN 706
685 PRINT "MOTIONAL IMPEDANCE DATA IN ";C$ @ PRINT USING
 686
686 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
700 GCLEAR @ CLEAR
705 GOSUB 8100
706 CLEAR @ BEEP @ BEEP
710 DISP "WANT A PLOT?(1=YES,2=NO)"
715 INPUT Y2
720 IF Y2=2 THEN 755
721 PLOTTER IS 705 @ PEN 1
725 GOSUB 8400
737 LDIR 0 @ PENUP
738 MOVE -(.5*L),-L-.2*L
740 LABEL "MOTIONAL ";S$;" PLOT IN ";C$
755 GCLEAR @ CLEAR
756 PRINT USING 757
757 IMAGE 3/
800 DISP "I AM DOING CALCULATIONS FOR YOU. PLEASE BE PAT
IENT."
803 IF M=2 THEN 1040
810 IF T$="M" THEN 1000
825 IF L2=2 THEN 860
840 Q0=E1/ABS(E4-E6)
845 C1=ABS(E2/(2*PI*F0))
855 GOTO 885
860 Q8=E1/ABS(E4-E6)
865 C1=ABS(1/(2*PI*F8*E2))
885 K=1-(F0/F8)^2
895 K1=C1/(ABS(C0)+C1)
930 GOSUB 9000
931 PRINTER IS 2
940 GOTO 1350
1000 K=1-(F8/F0)^2
1005 IF L2=2 THEN 1025
1010 Q0=E1/ABS(E4-E6)
1015 GOTO 1030
1025 Q8=E1/ABS(E4-E6)
1030 GOSUB 9200
1031 PRINTER IS 2 @ GOTO 1350
1040 IF T$="M" THEN 1150
```

```
1041 DISP "IF YOU HAVE DATA FOR AIR, ENTER 1; ELSE 2"
1042 INPUT Y
1043 RAD
1044 IF L2=1 THEN 1110
1045 IF Y=2 THEN 1062
1060 P6=D4*(D3-D4)/(D3*R7)
1061 W0=F1
1062 Q1=E1/ABS(E4-E6) @ K=1-(F1/F9)^2
1070 GOSUB 9100
1076 PRINTER IS 2 @ GOTO 1350
1110 IF Y=2 THEN 1135
1126 W0=F1
1130 P6=D2*(D1-D2)/(D1*G7)
1135 Q1=E1/ABS(E4-E6)
1140 K=1-(F1/F9)^2
1145 GOSUB 9100
1146 PRINTER IS 2 @ GOTO 1350
1150 RAD
1151 DISP "IF YOU HAVE DATA FOR AIR, ENTER 1; ELSE 2"
1152 INPUT Y
1153 IF L2=1 THEN 1180
1154 IF Y=2 THEN 1162
1155 B=.5*ACS((R7-R9)/D4)
1156 H8=SIN(B)^2 @ H9=COS(B)^2
1157 P5=((1+D3/R0*H9)^.5-(1-D3/R0*H8)^.5)/((1+D3/R0*H9)^
.5+(1-D3/R0*H8)^.5)
1159 P=D4*SIN(2*B)/(4*R9*Q9) @ W0=F9*(2*P+(P^2+1)^.5)
1160 P6=D4*(D3-D4)/(D3*R7)
1162 Q9=E1/ABS(E4-E6) @ K=1-(F9/F1)^2
1163 PRINT "B=";B,"K=";K,"K1=";K1,"H8=";H8,"H9=";H9
1164 GOSUB 9300
1168 PRINTER IS 2 @ GOTO 1350
1180 RAD
1182 IF Y=2 THEN 1210
1184 B=.5*ACS((G7-G9)/D2)
1186 H8=SIN(B)^2 @ H9=COS(B)^2
1188 P5=((1+D1/G0*H9)^.5-(1-D1/G0*H8)^.5)/((1+D1/G0*H9)^
.5+(1-D1/G0*H8)^.5)
1190 P=D2*SIN(2*B)/(4*G9*Q1) @ W0=F1*(2*P+(P^2+1)^.5)
1195 P6=D2*(D1-D2)/(D1*C7)
1210 Q9=E1/ABS(E4-E6) @ K=1-(F9/F1)^2
1211 PRINT "B=";B,"K=";K,"K1=";K1,"H8=";H8,"H9=";H9
1215 GOSUB 9300
1225 PRINTER IS 2 @ CLEAR @ BEEP
1350 DISP "DO YOU DESIRE ANOTHER IN THIS MEDIUM?(TO GET
THE OTHER TYPE DATA?)(1=YES,2=NO)"
1355 INPUT Z1
1357 PLOTTER IS 1
1360 IF Z1=1 THEN 152
1361 PRINT USING 1362
```

```
1362 IMAGE 3/
1365 DISP "DO YOU DESIRE A RUN IN ANOTHER MEDIUM?(1=YES,
2=NO)"
1370 INPUT Z1
1375 IF Z1=1 THEN 45
1380 DISP "JUST FOR THE RECORD, INPUT WATER TEMP, AIR TE
MP, TRANSDUCER SER NO, MODEL NO.,"
1381 DISP "AND TYPE (E OR M)"
1385 DISP "INPUT ''0'' IF INFO IS UNKNOWN"
1390 INPUT W,A,S,N,L$
1391 PRINTER IS 701,76
1400 PRINT "WATER TEMP=";W,,"AIR TEMP=";A,,"SER. NO.=";S
,,"MODEL NO.=";N,,"TYPE ";L$
1410 GOTO 9998
2501 REM *SHUNT*
2503 CLEAR @ BEEP @ DISP "WE ARE FINDING SHUNT VALUES FO
R G/B OR R/X."
2510 A$="FR" @ B$="HZ" @ S1=1
2511 IF T$="M" THEN 2520
2512 IF M=2 THEN 2516
2513 Q=MAX(Q0,Q6) @ F=F0-(Z2-2)*F0/Q
2514 IF F>200 THEN 2535
2515 F=200+(F0-2*F0/Q-200)/50 @ GOTO 2535
2516 Q=MAX(Q1,Q9) @ F=F1-(Z2-2)*F1/Q
2517 IF F>200 THEN 2535
2518 F=200+(F1-2*F1/Q-200)/50 @ GOTO 2535
2520 IF M=2 THEN 2524
2521 Q=MAX(Q0,Q8) @ F=F8-(Z2-2)*F8/Q
2522 IF F>200 THEN 2535
2523 F=200+(F8-2*F8/Q-200)/50 @ GOTO 2535
2524 Q=MAX(Q1,Q9) @ F=F9-(Z2-2)*F9/Q
2525 IF F>200 THEN 2535
2527 F=200+(F9-2*F9/Q-200)/50
2535 D$=VAL$(F)
2537 OUTPUT 717 ;A$,D$,B$
2538 WAIT 1000
2540 DISP "SET DRANETZ FREQ. SCALE TO COVER FREQ. ON SYN
THESIZER.ZERO METERS.SET ON FS.(CONT)"
2541 PAUSE
2542 DISP "HERE WE GET THE NORMALIZATION FACTORS."
2543 OUTPUT 709 ;"VT1"
2548 GOSUB 8549
2550 G,B,R,X=0
2551 A$="FR" @ B$="HZ" @ D$=VAL$(F)
2553 OUTPUT 717 ;A$,D$,B$
2561 CLEAR @ DISP "SET DRANETZ ON Y,SET SCALE,SET ON NOR
M FOR FILTER + PHASE,PLUG IN TRANSDUCER."
2562 BEEP @ DISP "ENTER SCALE FACTOR IN MICROMHOS.SAME S
CALE AS FOR DATA.(WE GET SHUNT G/B)"
2564 INPUT S6@ CLEAR @ DISP "I AM WORKING TO GET SHUNT V
```

```
ALUES" @ BEEP
2565 FOR I=1 TO 10
2566 OUTPUT 717 ;A$,D$,B$
2567 WAIT 1000
2568 OUTPUT 709 ;"AC3"
2569 ENTER 709 ; M(I)
2570 G=G+M(I)
2571 OUTPUT 709 ;"AC4"
2572 ENTER 709 ; N(I)
2573 B=B+N(I)
2574 NEXT I
2575 G=G/(I-1) @ B=B/(I-1)
2576 G=G*S8/N8 @ B=B*S8/N9 @ BEEP
2578 DISP "SET DRANETZ ON Z;SET SCALE FOR MAX RESPONSE.M
OVE TRANS. INPUT. ENTER SCALE FACTOR"
2579 INPUT S8@ CLEAR @ DISP "I AM WORKING TO GET SHUNT V
ALUES"
2580 FOR I=1 TO 10
2581 OUTPUT 717 ;A$,D$,B$
2582 WAIT 1000
2583 OUTPUT 709 ;"AC3"
2584 ENTER 709 ; M(I)
2585 R=R+M(I)
2586 OUTPUT 709 ;"AC4"
2587 ENTER 709 ; N(I)
2588 X=N(I)+X
2589 NEXT I
2590 R=R/(I-1) @ X=X/(I-1)
2591 R=R*S8/N8 @ X=X*S8/N9
2592 IF T$="M" THEN 2610
2595 IF M=1 THEN 2600
2596 R9=R @ X9=X @ G9=G @ B9=B @ GOTO 2601
2600 G0=G @ B0=B @ R0=R @ X0=X
2601 PRINT "SHUNT VALUES"
2602 PRINT USING 2603
2603 IMAGE 1/
2605 PRINT "G0=";G0,,"B0=";B0,,"R0=";R0,,"X0=";X0,,"G9="
;G9,,"B9=";B9,,"R9=";R9,,"X9=";X9
2606 PRINT @ GOTO 2630
2610 IF S1=2 THEN 2620
2611 J1=G @ J2=B @ J3=R @ J4=X
2612 IF M=2 THEN 2615
2613 F=F8+(Z2-2)*F8/Q @ S1=2 @ GOTO 2550
2615 F=F9+(Z2-2)*F9/Q @ S1=2 @ GOTO 2550
2620 G=.5*(G+J1) @ B=.5*(B+J2) @ R=.5*(R+J3) @ X=.5*(J4+
X) @ GOTO 2595
2630 GCLEAR @ CLEAR @ BEEP
2635 DISP "ENTER '1' IF ALL IS WELL; '2' IF YOU NEED A R
EPEAT."
2640 INPUT Y
```

```
2645 IF Y=2 THEN 2501
2650 RETURN
7000 REM **F-Q**
7001 GCLEAR @ CLEAR
7005 DISP "ENTER LOWER, UPPER FREQ. FOR SWEEP.IF RESONAN
CE UNKNOWN USE 10000,200000. (F1,F2)"
7010 INPUT F4,F2
7011 DISP "ENTER RMS VOLTAGE NEEDED.(3000 MV FOR LOW FRE
Q. AS LOW AS 2000 MV FOR HIGH)"
7012 INPUT A@ A1$=VAL$(A)
7020 CLEAR @ BEEP
7025 A$="AM" @ B$="MR"
7035 OUTPUT 717 ;A$,A1$,B$
7040 OUTPUT 709 ;"AC3VT3"
7045 F3=CEIL((F2-F4)/300)
7060 CLEAR @ DISP "I AM WORKING TO GET THE SPECTRUM DATA
 FOR YOU,THEN WILL SHOW & MAKE A PLOT"
7065 FOR I=1 TO 300
7070 D(I,1)=F4+I*F3
7075 A$="HZ" @ B$="FR"
7080 D$=VAL$(D(I,1))
7085 OUTPUT 717 ;B$,D$,A$
7090 OUTPUT 709 ;"AC3VT3"
7095 WAIT 100
7100 ENTER 709 ; D(I,2)
7105 NEXT I
7110 F5=F4-.1*(F2-F4) @ F6=F2+.1*(F2-F4)
7115 F6=F2+.1*(F2-F4)
7119 PLOTTER IS 1 @ GCLEAR @ CLEAR
7125 SCALE F5,F6,-.1,1.2
7130 XAXIS 0,2000,F4,F2
7135 YAXIS F4,.1,-.1,1.2
7140 FOR I=1 TO 300
7145 PENUP
7150 PLOT D(I,1),D(I,2)
7155 NEXT I
7158 GRAPH @ COPY
7160 DISP "NEED ANOTHER RUN? (1=YES,2=NO)"
7161 INPUT Y
7162 IF Y=1 THEN 7005
7163 CLEAR @ GCLEAR @ BEEP
7165 DISP "ENTER DECISION POINT FOR AMPLITUDE (0 TO 1.2)
.(LESS THAN THE MAX DISPLAYED)."
7170 INPUT S@ CLEAR @ BEEP
7180 PRINT "AMPLITUDE IN VOLTS";"   FREQUENCY"
7181 PRINT
7190 FOR I=1 TO 300
7195 IF D(I,2)<S THEN 7210
7200 PRINT USING 7205 ; D(I,2),D(I,1)
7205 IMAGE 1X,D.DDDDDDDD,10X,DDDDDD.DD
```

```
7210 NEXT I
7215 PRINT USING 7220
7220 IMAGE 3/
7225 CLEAR @ BEEP
7226 DISP "IF YOU ARE READY TO CONTINUE ENTER ''1''; OTHER
WISE ENTER ''2''."
7227 INPUT Y
7228 IF Y=2 THEN 7160
7235 DISP "WHAT IS CENTER FREQ, HALFWIDTH TO CONSIDER?"
7236 INPUT F,N@ CLEAR @ BEEP
7240 DISP "I AM WORKING TO GET GOOD FREQ AND Q DATA"
7241 FOR I=1 TO 300
7242 D(I,1)=F-N+I*N/150
7243 A$="HZ" @ B$="FR"
7245 D$=VAL$(D(I,1))
7255 OUTPUT 717 ;B$,D$,A$
7260 OUTPUT 709 ;"AC3VT3"
7265 WAIT 100
7270 ENTER 709 ; D(I,2)
7275 NEXT I
7285 CLEAR @ GCLEAR @ DISP "I AM FINDING THE ABSOLUTE MA
X AND FREQ UPPER AND LOWER"
7290 B1,B4=0 @ H,H1,H2,H3,H4=1
7295 B2,B3=50
7300 FOR I=2 TO 300
7310 IF D(I,2)<D(H,2) THEN 7340
7315 IF D(I,2)=D(H,2) THEN 7325
7325 A6=D(I,2) @ F6=D(I,1) @ H=I
7340 NEXT I
7345 A7=A6/2
7350 FOR I=1 TO H
7355 IF A7=D(I,2) THEN 7405
7360 IF A7<D(I,2) THEN 7385
7365 IF D(I,2)<B1 THEN 7425
7370 B1=D(I,2) @ H1=I @ GOTO 7425
7385 IF D(I,2)>B2 THEN 7400
7390 B2=D(I,2) @ H2=I
7400 GOTO 7425
7405 B1,B2=D(I,2) @ H1,H2=I @ F7=D(H2,1) @ GOTO 7440
7425 NEXT I
7430 X=(A7-B1)/(B2-B1)
7435 F7=X*(D(H2,1)-D(H1,1))+D(H1,1)
7440 FOR I=H TO 300
7445 IF A7=D(I,2) THEN 7495
7450 IF A7>D(I,2) THEN 7475
7455 IF D(I,2)>B3 THEN 7470
7460 B3=D(I,2) @ H3=I
7470 GOTO 7515
7475 IF D(I,2)<=B4 THEN 7490
7480 B4=D(I,2) @ H4=I
```

```
7490 GOTO 7515
7495 B3,B4=D(I,2) @ H3,H4=I
7505 L5=D(H3,1)
7510 GOTO 7530
7515 NEXT I
7520 X=(A7-B4)/(B3-B4)
7525 L5=-(X*(D(H4,1)-D(H3,1)))+D(H4,1)
7530 Q=F6/(L5-F7)
7535 PRINT "CENTER FREQ IS ";F6
7536 PRINT "Q IS ";Q
7538 DISP "IF YOU ARE READY TO PROCEED, ENTER ''1'. TO RE
RUN FOR BETTER VALUES, ENTER ''2'."
7539 INPUT Y
7540 IF Y=2 THEN 7235
7545 RETURN
8100 REM **DATA LIST**
8101 PRINTER IS 2
8102 FOR I=99 TO 199
8103 PRINT USING 8105 ; D(I,1) ,D(I,2) ,D(I,3)
8105 IMAGE DDDDDD.D,2X,D.DDDE  ,2X,D.DDDE
8106 NEXT I
8107 PRINT USING 8108
8108 IMAGE 3/
8110 RETURN
8200 REM **PLOT RE**
8201 GCLEAR @ CLEAR
8202 H8=D(1,1)-.15*(D(300,1)-D(1,1))
8203 H9=D(300,1)+.1*(D(300,1)-D(1,1))
8205 PLOTTER IS 705 @ PEN 1
8209 SCALE H8,H9,-(.8*E),E+.25*E
8210 XAXIS 0,(D(300,1)-D(1,1))/10,D(1,1),D(300,1)
8211 YAXIS D(1,1),E/5,-(.8*E),E+.2*E
8212 PENUP
8215 FOR I=1 TO 300
8216 PLOT D(I,1),D(I,2)
8217 NEXT I
8218 PENUP @ DEG @ LDIR 0,SIN(90)
8221 FOR L1=D(1,1) TO D(300,1) STEP (D(300,1)-D(1,1))/10
 @ PENUP
8222 MOVE L1,-(.18*E)
8223 LABEL INT(L1)
8224 NEXT L1
8226 LDIR 0 @ PENUP
8227 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-(.7*E)
8228 LABEL "FREQUENCY (HZ)"
8230 PENUP @ PEN 1
8232 LDIR 0
8234 FOR L1=-(.8*E) TO E+.2*E STEP E/5 @ PENUP
8235 MOVE D(1,1)-.09*(D(300,1)-D(1,1)),L1
8236 LABEL INT(L1)
```

```
8237 NEXT L1
8240 LDIR 0,SIN(90)
8241 MOVE D(1,1)-.1*(D(300,1)-D(1,1)),.1*E
8243 LABEL H$
8250 RETURN
8300 REM **PLOT IM**
8301 GCLEAR @ CLEAR
8303 H8=D(1,1)-.15*(D(300,1)-D(1,1))
8304 H9=D(300,1)+.1*(D(300,1)-D(1,1))
8305 L=MAX(ABS(E5),ABS(E3))
8306 PLOTTER IS 705 @ PEN 1
8312 SCALE H8,H9,-L-.5*L,L+.25*L
8313 XAXIS 0,(D(300,1)-D(1,1))/10,D(1,1),D(300,1)
8314 YAXIS D(1,1),L/5,-L-.2*L,L+.2*L
8315 PENUP
8318 FOR I=1 TO 300
8325 PLOT D(I,1),D(I,3)
8330 NEXT I
8331 PENUP @ DEG @ LDIR 0,SIN(90)
8333 FOR L1=D(1,1) TO D(300,1) STEP (D(300,1)-D(1,1))/10
 @ PENUP
8335 MOVE L1,-L-.2*L
8336 LABEL INT(L1)
8337 NEXT L1
8340 LDIR 0 @ PENUP
8341 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-L-.4*L
8342 LABEL "FREQUENCY (HZ)"
8345 PENUP @ PEN 1 @ LDIR 0
8352 FOR L1=-L-.2*L TO L+.2*L STEP L/5 @ PENUP
8355 MOVE D(1,1)-.09*(D(300,1)-D(1,1)),L1
8356 LABEL INT(L1)
8357 NEXT L1
8360 PENUP @ PEN 1 @ LDIR 0,SIN(90)
8361 MOVE D(1,1)-.1*(D(300,1)-D(1,1)),-(L*.5)
8368 LABEL G$
8380 RETURN
8400 REM **CIRCLES**
8401 GCLEAR @ CLEAR
8402 L1=MAX(ABS(E3),ABS(E5))
8403 L=MAX(ABS(E),L1)
8404 PLOTTER IS 705 @ PEN 1
8406 SCALE 1.25*(-L-.1*L),1.25*(L+.1*L),-L-.2*L,L+.15*L
8407 XAXIS 0,L/5,-L-.1*L,L+.1*L
8408 YAXIS 0,L/5,-L-.1*L,L+.1*L
8409 PENUP @ PEN 1
8411 FOR I=1 TO 300
8412 PLOT D(I,2),D(I,3)
8413 NEXT I
8414 PENUP
8415 LDIR 0 @ PEN 1 @ PENUP
```

```
8416 MOVE -(L*.5),-L-.1*L
8418 LABEL H$
8420 PENUP @ PEN 1 @ DEG
8425 LDIR 0,SIN(90)
8426 FOR L1=-L-.1*L TO L+.1*L STEP L/5 @ PENUP
8427 MOVE L1,-L
8428 LABEL INT(L1)
8429 NEXT L1
8435 LDIR 0 @ PEN 1 @ PENUP
8436 FOR L1=-L-.1*L TO L+.1*L STEP L/5 @ PENUP
8437 MOVE -(.886*L),L1
8438 LABEL INT(L1)
8439 NEXT L1
8445 LDIR 0,SIN(90)
8446 MOVE -(.95*L),-(.3*L)
8448 LABEL G$
8450 RETURN
8549 REM **NORM**
8550 N8,N9=0
8551 FOR I=1 TO 10
8557 WAIT 500
8558 OUTPUT 709 ;"AC3"
8559 ENTER 709 ; N(I)
8560 N8=N8+N(I)
8565 OUTPUT 709 ;"AC4"
8566 ENTER 709 ; M(I)
8567 N9=N9+M(I)
8568 NEXT I
8569 N8=N8/(I-1)
8570 N9=-(N9/(I-1))
8572 PRINT USING 8573
8573 IMAGE 3/
8575 RETURN
8600 REM **VALUES**
8601 CLEAR @ BEEP
8602 DISP "I AM COLLECTING THE DATA NOW"
8605 IF L2=1 AND M=2 THEN 8620
8606 IF L2=1 AND M=1 THEN 8621
8607 IF L2=2 AND M=1 THEN 8622
8608 IF L2=2 AND M=2 THEN 8623
8620 F6=F1 @ Q=Q1 @ GOTO 8625
8621 F6=F0 @ Q=Q0 @ GOTO 8625
8622 F6=F8 @ Q=Q8 @ GOTO 8625
8623 F6=F9 @ Q=Q9
8625 FOR I=1 TO 50
8628 IF F6-Z2*F6/Q+(Z2-2)*F6/(50*Q)>200 THEN 8631
8629 D(I,1)=200+(F6-2*F6/Q-200)*I/50
8630 GOTO 8632
8631 D(I,1)=F6-Z2*F6/Q+I*(Z2-2)*F6/(50*Q)
8632 D$=VAL$(D(I,1))
```

```
8633 OUTPUT 717 ;A$,D$,E$
8634 WAIT 150
8635 OUTPUT 709 ;"AC3VT3"
8636 ENTER 709 ; H8
8637 D(I,2)=H8*S8/N8
8638 OUTPUT 709 ;"AC4VT3"
8639 ENTER 709 ; H9
8640 D(I,3)=H9*S8/N9
8641 NEXT I
8650 FOR I=51 TO 250
8651 D(I,1)=F6-2*F6/Q+(I-50)*2*F6/(100*Q)
8652 D$=VAL$(D(I,1))
8653 OUTPUT 717 ;A$,D$,E$
8654 WAIT 250
8655 OUTPUT 709 ;"AC3VT3"
8656 ENTER 709 ; H8
8657 D(I,2)=H8*S8/N8
8658 OUTPUT 709 ;"AC4VT3"
8659 ENTER 709 ; H9
8660 D(I,3)=H9*S8/N9
8661 NEXT I
8670 FOR I=251 TO 300
8671 D(I,1)=F6+2*F6/Q+(I-250)*(Z2-2)*F6/(50*Q)
8672 D$=VAL$(D(I,1))
8673 OUTPUT 717 ;A$,D$,E$
8674 WAIT 150
8675 OUTPUT 709 ;"AC3VT3"
8676 ENTER 709 ; H8
8677 D(I,2)=H8*S8/N8
8678 OUTPUT 709 ;"AC4VT3"
8679 ENTER 709 ; H9
8680 D(I,3)=H9*S8/N9
8681 NEXT I
8682 CLEAR @ DISP "I AM FINDING MIN/MAX VALUES & ASSOC.
FREQS"
8683 GOSUB 8700
8684 IF L2=2 THEN 8687
8685 PRINT "GMAX=";E,,"FGMX=";E1,,"BGMX=";E2,,"BMX=";E3,
,"FBMX=";E4,,"BMI=";E5,,"FBMI=";E6
8686 GOTO 8697
8687 PRINT "RMAX=";E,,"FRMX=";E1,,"XFMX=";E2,,"XMX=";E3,
,"FXMX=";E4,,"XMI=";E5,,"FXMI=";E6
8697 DISP "IF ALL IS WELL, ENTER ''1''. ENTER ''2'' TO RETAK
E DATA."
8698 INPUT Y
8699 RETURN
8700 REM **MAXMIN**
8703 H,H1,H2=100
8705 E=D(100,2) @ E1,E4,E6=D(100,1) @ E2,E3,E5=D(100,3)
8706 FOR I=101 TO 200
```

```
8710 IF D(I,2)<D(H,2) THEN 8725
8711 IF D(I,2)=D(H,2) THEN 8720
8720 E=D(I,2) @ E1=D(I,1) @ E2=D(I,3) @ H=I
8725 IF D(I,3)<D(H1,3) THEN 8740
8726 IF D(I,3)=D(H1,3) THEN 8735
8735 E3=D(I,3) @ E4=D(I,1) @ H1=I
8740 IF D(I,3)>=D(H2,3) THEN 8751
8745 H2=I @ E5=D(I,3) @ E6=D(I,1)
8751 NEXT I
8760 J1=D(H,2) @ J2=(D(H+1,2)-D(H-1,2))/2 @ J3=(D(H+1,2)
+D(H-1,2)-2*J1)/2
8762 F6=-(J2/(2*J3))
8764 A=J1+J2+F6+J3*F6^2
8770 F6=D(H,1)+F6*(D(H,1)-D(H-1,1))
8775 E1=F6 @ E=A
8788 D=ABS(E3-E5)
8789 IF M=2 THEN 8793
8790 IF L2=1 THEN 8792
8791 D3=D @ GOTO 8796
8792 D1=D @ GOTO 8796
8793 IF L2=1 THEN 8795
8794 D4=D @ GOTO 8796
8795 D2=D
8796 PRINT "D1=";D1,,"D2=";D2,,"D3=";D3,,"D4=";D4
8799 RETURN
9000 REM **CALC-A**
9001 PRINTER IS 701,76
9002 PRINT @ PRINT
9003 PRINT "VALUES MEASURED IN AIR FROM ";S$;" DATA"
9004 PRINT
9011 PRINT "BLOCKED CAPACITANCE= ";ABS(C0);" FARADS AT "
;F;"HZ"
9012 PRINT "ELECTRICAL QUALITY FACTOR = ";Q0
9013 PRINT "MECHANICAL QUALITY FACTOR = ";Qo
9014 PRINT "ELECTRICAL RESONANCE =";F0;" HZ"
9015 PRINT "MECHANICAL RESONANCE = ";F8;" HZ"
9016 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9017 PRINT "STATIC COUPLING COEFFICIENT= ";K1
9021 PRINT "BLOCKED RESISTANCE=";R0;"OHMS"
9031 PRINT USING 9032
9032 IMAGE 2/
9050 RETURN
9100 REM **CALC-W**
9101 PRINTER IS 701,76
9102 PRINT @ PRINT
9103 PRINT "VALUES  FOR MEASUREMENTS IN WATER FROM ";S$;
" DATA"
9104 PRINT
9111 PRINT "BLOCKED CAPACITANCE = ";ABS(C0);" FARADS AT
```

```
";F;"HZ"
9112 PRINT "ELECTRICAL QUALITY FACTOR = ";Q1
9113 PRINT "MECHANICAL QUALITY FACTOR = ";Q9
9114 PRINT "ELECTRICAL RESONANCE = ";F1;" HZ"
9115 PRINT "MECHANICAL RESONANCE = ";F9;" HZ"
9116 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9120 PRINT "MECHANICAL POWER UTILIZATION FACTOR";ABS(P6)

9121 PRINT " STATIC COUPLING COEFFICIENT=";K1
9122 PRINT "BLOCKED RESISTANCE =";R9;"OHMS"
9132 PRINT USING 9133
9133 IMAGE 3/
9150 RETURN
9200 REM **CALC-A/M**
9201 PRINTER IS 701,76
9202 PRINT @ PRINT
9203 PRINT "VALUES MEASURED IN AIR FROM ";S$;" DATA"
9204 PRINT
9211 PRINT "BLOCKED INDUCTANCE= ";ABS(L0);" HENRIES AT "
;F6;"HZ"
9212 PRINT "ELECTRICAL QUALITY FACTOR = ";Q0
9213 PRINT "MECHANICAL QUALITY FACTOR = ";Q8
9214 PRINT "ELECTRICAL RESONANCE =";F0;" HZ"
9215 PRINT "MECHANICAL RESONANCE = ";F8;" HZ"
9216 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9217 PRINT "BLOCKED RESISTANCE= ";R;"OHMS"
9231 PRINT USING 9232
9232 IMAGE 2/
9250 RETURN
9300 REM **CALC-W/M**
9301 PRINTER IS 701,76
9302 PRINT @ PRINT
9303 PRINT "VALUES  FOR MEASUREMENTS IN WATER FROM ";S$;
" DATA"
9304 PRINT
9311 PRINT "BLOCKED INDUCTANCE = ";ABS(L0);" HENRIES AT
";F6;"HZ"
9312 PRINT "ELECTRICAL QUALITY FACTOR = ";Q1
9313 PRINT "MECHANICAL QUALITY FACTOR = ";Q9
9314 PRINT "ELECTRICAL RESONANCE = ";F1;" HZ"
9315 PRINT "MECHANICAL RESONANCE = ";F9;" HZ"
9316 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9318 PRINT "POTENTIAL EFFICIENCY = ";P5
9319 PRINT "FREQUENCY OF OPTIMUM EFFICIENCY = ";W0;" HZ"

9320 PRINT "MECHANICAL POWER UTILIZATION FACTOR";ABS(P6)
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```
9322 PRINT USING 9323
9323 IMAGE 3/
9350 RETURN
9998 DISP "THE END"
9999 END
```

```
1 REM **PICKBW**
2 OPTION BASE 1
3 SHORT Q0,Q1,Q8,Q9,Q,E,E2,E3,E5,R8,R7,X2,X3,X5,X6,X7,X8
,G7,G8,B2,B3,B5,B6,B7,B8,K,K1,P5,P6,W
7 SHORT A,F2,F3,F4,F5,H3,H4,J1,J2,J3,J4,G,B,R,X
8 INTEGER M,Y,Y1,I,Y2,J,Z2,Z3,H1,H2,L2,S1
10 DIM B$[2],A$[2],T$[1],D(300,3),A1$[4],D$[300],L$[20],
R$[1],I$[1],S$[10],C$[5],G$[23],H$[23]
11 REAL S,N,N8,N9,R0,R9,X0,X9,L,C0,L0,O,P1,H8,H9,P,W0,G0
,G9,B0,B9,N(10),M(10),F0,F1,F6,F8,F9
14 REAL S8,E4,E6,L5,D,D1,D2,D3,D4
15 X6,D1,D2,D3,D4=0
16 Q,E2,E3,E5,R8,R7,X2,X3,X5=0
17 Z3,A,F2,F3,F4,F5,B6,B7,B8=0
18 S8,E4,E6,M,Y,Y1,I,Y2,J,Z2=0
19 K,K1,P5,P6,W,Q0,Q1,Q8,Q9,E=0
20 C0,L0,O,P1,B,H8,H9,P,W0,S=0
21 N,N8,N9,R0,R9,X0,X9,G0,G9=0
22 B0,B9,H1,H2,F0,F1,F6,F8,F9=0
24 DISP "THIS PROGRAM IS DESIGNED FOR AN EXPERIENCED OPE
RATOR. THE BANDWIDTH FOR DATA COLLECT."
25 DISP "AND FREQ. TO GET BLOCKED DATA WILL BE THE CHOIC
E OF THE OPERATOR. ''HYDRA2' PROGRAM IS"
26 DISP "DESIGNED TO COVER 10 X BW AUTOMATICALLY. HIT ''C
ONT' IF READY TO PROCEED."
27 PAUSE
28 CLEAR @ BEEP
35 DISP "ENTER TYPE OF TRANSDUCER TO BE MEASURED?('M' FO
R MAGNETIC COUPLING OR ''E' FOR ELEC.)"
42 INPUT T$@ DISP "TO GET A COMPLETE SET OF DATA YOU NEE
D MEASUREMENTS IN BOTH AIR AND WATER. "
45 DISP "DO AIR FIRST.IN WHAT MEDIUM ARE YOU OPERATING?(
ENTER ''1' FOR AIR OR ''2' FOR WATER)"
46 INPUT M@ CLEAR @ BEEP
47 IF M=2 THEN 49
48 C$="AIR" @ GOTO 51
49 C$="WATER"
51 PRINTER IS 2 @ PLOTTER IS 1
55 DISP "SET THE DRANETZ FOR ADMITTANCE.SET ON LOWEST SC
ALE THAT WON'T PEAK DURING RUN.(CONT)"
60 PAUSE
65 PRINT @ PRINT @ PRINT
70 PRINT "ADMITTANCE IN ";C$
75 GOSUB 7000
80 IF M=2 THEN 90
85 F0=F6 @ Q0=Q @ GOTO 100
90 F1=F6 @ Q1=Q
100 GCLEAR @ CLEAR @ BEEP
105 DISP "SET DRANETZ FOR IMPEDANCE-(SCALE NEEDED)-HIT C
ONT "
```

```
110 PAUSE
115 PRINT @ PRINT @ PRINT
120 PRINT "IMPEDANCE IN ";C$
125 GOSUB 7000
130 IF M=2 THEN 140
135 F8=F6 @ Q8=Q @ GOTO 141
140 F9=F6 @ Q9=Q
141 CLEAR @ BEEP
142 PRINTER IS 701,76 @ PRINT USING 144
144 IMAGE 2/
145 PRINT "F(Y-AIR)= ";INT(F0),,"F(Y-WAT)= ";INT(F1),,"F
(Z-AIR)= ";INT(F8),,"F(Z-WAT)=";INT(F9)
146 PRINT "Q(Y-AIR)= ";Q0,,"Q(Y-WATER)= ";Q1,,"Q(Z-AIR)=
 ";Q8,,"Q(Z-WATER)= ";Q9
147 PRINTER IS 2
148 CLEAR @ DISP "THESE ARE THE INITIAL ESTIMATES.(HIT ''
CONT' WHEN READY TO PROCEED)"
149 PAUSE
150 GOSUB 2501
152 CLEAR @ BEEP
153 DISP "TO COLLECT ADMITTANCE DATA (FOR ELEC. COUPLING
) ENTER ''1'. ENTER ''2' FOR IMPEDANCE"
154 INPUT L2@ PRINTER IS 2
155 IF L2=2 THEN 158
156 R$="G" @ I$="B" @ S$="ADMITTANCE" @ H$="CONDUCTANCE
(MICROMHOS)" @ G$="SUSCEPTANCE (MICROMHOS)"
157 GOTO 159
158 R$="R" @ I$="X" @ S$="IMPEDANCE" @ G$="REACTANCE (OH
MS)" @ H$="RESISTANCE (OHMS)"
159 IF L2=1 THEN 176
160 CLEAR @ DISP "SET ON Z AND ENTER SCALE FACTOR TO COL
LECT DATA."
161 INPUT S8@ PRINT S$;" IN ";C$ @ PRINT "SCALE =";S8;"
OHMS"
162 CLEAR
164 GOSUB 8600
165 IF Y=2 THEN 152
166 IF M=2 THEN 169
167 R8=E @ X3=E2 @ X8=E3 @ F4=E4
168 X6=E5 @ F5=E6 @ F8=E1 @ GOTO 196
169 R7=E @ X2=E2 @ X7=E3 @ F4=E4
170 X5=E5 @ F5=E6 @ F9=E1 @ GOTO 196
176 CLEAR @ BEEP
177 DISP "SET ON Y & ENTER SCALE FACTOR IN MICROMHOS TO
COLLECT DATA."
178 INPUT S8@ PRINT S$;" IN ";C$ @ PRINT "SCALE =";S8;"
MICROMHOS"
179 GOSUB 8600
180 IF Y=2 THEN 152
181 IF M=2 THEN 185
```

```
182 G8=E @ B3=E2 @ B8=E3 @ F2=E4
183 B6=E5 @ F3=E6 @ F0=E1 @ GOTO 198
185 G7=E @ B2=E2 @ B7=E3
186 F2=E4 @ B5=E5 @ F3=E6 @ F1=E1
198 PRINT USING 199
199 IMAGE 2/
200 BEEP @ DISP "DO YOU DESIRE A LIST OF DATA NEAR RESON
ANCE? (100 POINTS)(1=YES,2=NO)"
201 INPUT Y
202 IF Y=2 THEN 300
204 IF L2=2 THEN 240
210 PRINT "ADMITTANCE DATA FOR ";C$;" IN MICROMHOS" @ PR
INT USING 215
215 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
216 GOTO 265
240 PRINT "IMPEDANCE DATA FOR ";C$;" IN OHMS" @ PRINT US
ING 215
265 GOSUB 8100
300 CLEAR @ BEEP @ DISP "DO YOU DESIRE A PLOT OF DATA?(1
=YES,2=NO)"
305 INPUT Y@ GCLEAR @ CLEAR
315 IF Y=2 THEN 450
320 DISP "ENTER: 1= G/R VS. FREQ; 2= B/X VS. FREQ; 3= B
VS. G/X VS. R; 4= END PLOTTING LOOP."
325 INPUT Y
330 IF Y=2 THEN 385
335 IF Y=3 THEN 425
340 IF Y=4 THEN 450
345 GOSUB 8200
356 LDIR 0 @ PEN 1 @ PENUP
357 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-(E*.8)
360 LABEL R$;" VS. FREQUENCY IN ";C$
361 GOTO 320
385 GOSUB 8300
397 LDIR 0 @ PEN 1 @ PENUP
398 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-L-.5*L
400 LABEL I$;" VS. FREQUENCY IN ";C$
401 GOTO 320
425 GCLEAR @ CLEAR @ GOSUB 8400
431 PEN 1
442 LDIR 0 @ PENUP
443 MOVE -(.5*L),-L-.2*L
445 LABEL "INPUT ELECTRICAL ";S$;" PLOT (";I$;"VS.";R$;"
) IN ";C$
446 GOTO 320
450 IF L2=2 THEN 645
451 IF T$="E" THEN 525
452 GCLEAR @ CLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
465 C0=B*.000001/(2*PI*F6)
```

```
466 L0=1/((2*PI*F6)^2*C0)
470 FOR I=1 TO 300
475 D(I,2)=D(I,2).-G
480 D(I,3)=D(I,3).-D(I,1)*B/F6
485 NEXT I
490 GOSUB 8700
500 GOTO 542
525 GCLEAR @ CLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
532 C0=B*.000001/(2*PI*F)
535 FOR I=1 TO 300
536 D(I,2)=D(I,2).-G
537 D(I,3)=D(I,3).-D(I,1)*B/F
538 NEXT I
540 GOSUB 8700
542 BEEP @ DISP "DO YOU DESIRE A LIST OF MOTIONAL DATA N
EAR RESONANCE?(1=YES, 2=NO)"
543 INPUT Y
545 IF Y=2 THEN 604
575 PRINT "MOTIONAL ADMITTANCE DATA IN ";C$ @ PRINT USIN
G 580
580 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
595 GCLEAR @ CLEAR
600 GOSUB 8100
604 CLEAR @ BEEP @ BEEP
605 DISP "WANT A PLOT?(1=YES,2=NO)"
610 INPUT Y2
615 IF Y2=2 THEN 755
616 PLOTTER IS 705 @ PEN 1
620 GOSUB 8400
628 LDIR 0 @ PENUP @ PEN 1
629 MOVE -(.5*L),-L-.2*L
630 LABEL "MOTIONAL ";S$;" PLOT FOR ";C$
642 GOTO 755
645 CLEAR @ GCLEAR @ DISP "I AM CALCULATING MOTIONAL DAT
A"
646 IF T$="M" THEN 658
647 FOR I=1 TO 300
648 D(I,2)=D(I,2)-F
649 C0=1/(2*PI*F*X)
650 L0=1/((2*PI*F6)^2*C0)
651 D(I,3)=D(I,3).-2*PI*D(I,1)*L0
652 NEXT I
653 GOSUB 8700
654 C0=ABS(C0) @ L0=ABS(L0)
655 BEEP @ DISP "DO YOU WANT A LIST OF THE DATA NEAR RES
ONANCE?(1=YES,2=NO)"
656 INPUT Y
657 GOTO 670
658 L0=X/(2*PI*F6)
```

```
662 FOR I=1 TO 300
663 D(I,2)=D(I,2).-R
664 D(I,3)=D(I,3).-D(I,1)*2*PI*L0
665 NEXT I
666 GOSUB 8700
667 BEEP @ DISP " DO YOU WANT A LIST OF DATA NEAR RESONA
NCE?(1=YES,2=NO)"
668 INPUT Y
670 IF Y=2 THEN 706
685 PRINT "MOTIONAL IMPEDANCE DATA IN ";C$ @ PRINT USING
 686
686 IMAGE 2/,"FREQUENCY",4X,"REAL",6X,"IMAGINARY"
700 GCLEAR @ CLEAR
705 GOSUB 8100
706 CLEAR @ BEEP @ BEEP
710 DISP "WANT A PLOT?(1=YES,2=NO)"
715 INPUT Y2
720 IF Y2=2 THEN 755
721 PLOTTER IS 705 @ PEN 1
725 GOSUB 8400
737 LDIR 0 @ PENUP
738 MOVE -(.5*L),-L-.2*L
740 LABEL "MOTIONAL ";S$;" PLOT IN ";C$
755 GCLEAR @ CLEAR
756 PRINT USING 757
757 IMAGE 3/
800 DISP "I AM DOING CALCULATIONS FOR YOU. PLEASE BE PAT
IENT."
803 IF M=2 THEN 1040
810 IF T$="M" THEN 1000
825 IF L2=2 THEN 860
840 Q0=E1/ABS(E4-E6)
845 C1=ABS(E2/(2*PI*F0))
855 GOTO 885
860 Q8=E1/ABS(E4-E6)
865 C1=ABS(1/(2*PI*F8*E2))
885 K=1-(F0/F8)^2
895 K1=C1/(ABS(C0)+C1)
930 GOSUB 9000
931 PRINTER IS 2
940 GOTO 1350
1000 K=1-(F8/F0)^2
1005 IF L2=2 THEN 1025
1010 Q0=E1/ABS(E4-E6)
1015 GOTO 1030
1025 Q8=E1/ABS(E4-E6)
1030 GOSUB 9200
1031 PRINTER IS 2 @ GOTO 1350
1040 IF T$="M" THEN 1150
1041 BEEP @ DISP "IF YOU HAVE DATA FOR AIR, ENTER 1; ELS
```

```
E 2"
1042 INPUT Y
1043 RAD
1044 IF L2=1 THEN 1110
1045 IF Y=2 THEN 1062
1060 P6=D4*(D3-D4)/(D3*R7)
1061 W0=F1
1062 Q1=E1/ABS(E4-E6) @ K=1-(F1/F9)^2
1070 GOSUB 9100
1076 PRINTER IS 2 @ GOTO 1350
1110 IF Y=2 THEN 1135
1126 W0=F1
1130 P6=D2*(D1-D2)/(D1*G7)
1135 Q1=E1/ABS(E4-E6)
1140 K=1-(F1/F9)^2
1145 GOSUB 9100
1146 PRINTER IS 2 @ GOTO 1350
1150 RAD
1151 DISP "IF YOU HAVE DATA FOR AIR, ENTER 1; ELSE 2"
1152 INPUT Y
1153 IF L2=1 THEN 1180
1154 IF Y=2 THEN 1162
1155 B=.5*ACS((R7-R9)/D4)
1156 H8=SIN(B)^2 @ H9=COS(B)^2
1157 P5=((1+D3/R0*H9)^.5-(1-D3/R0*H8)^.5)/((1+D3/R0*H9)^
.5+(1-D3/R0*H8)^.5)
1159 P=D4*SIN(2*B)/(4*R9*Q9) @ W0=F9*(2*P+(P^2+1)^.5)
1160 P6=D4*(D3-D4)/(D3*R7)
1162 Q9=E1/ABS(E4-E6) @ K=1-(F9/F1)^2
1163 PRINT "B=";B,"K=";K,"K1=";K1,"H8=";H8,"H9=";H9
1164 GOSUB 9300
1168 PRINTER IS 2 @ GOTO 1350
1180 RAD
1182 IF Y=2 THEN 1210
1184 B=.5*ACS((G7-G9)/D2)
1186 H8=SIN(B)^2 @ H9=COS(B)^2
1188 P5=((1+D1/G0*H9)^.5-(1-D1/G0*H8)^.5)/((1+D1/G0*H9)^
.5+(1-D1/G0*H8)^.5)
1190 P=D2*SIN(2*B)/(4*G9*Q1) @ W0=F1*(2*P+(P^2+1)^.5)
1195 P6=D2*(D1-D2)/(D1*G7)
1210 Q9=E1/ABS(E4-E6) @ K=1-(F9/F1)^2
1211 PRINT "B=";B,"K=";K,"K1=";K1,"H8=";H8,"H9=";H9
1215 GOSUB 9300
1225 PRINTER IS 2 @ GOTO 1350
1350 DISP "DO YOU DESIRE ANOTHER IN THIS MEDIUM?(TO GET
THE OTHER TYPE DATA?)(1=YES,2=NO)"
1355 INPUT Z1
1357 PLOTTER IS 1
1360 IF Z1=1 THEN 152
1361 PRINT USING 1362
```

```
1362 IMAGE 3/
1365 DISP "DO YOU DESIRE A RUN IN ANOTHER MEDIUM?(1=YES,
2=NO)"
1370 INPUT Z1
1375 IF Z1=1 THEN 45
1380 DISP "JUST FOR THE RECORD, INPUT WATER TEMP, AIR TE
MP, TRANSDUCER SER NO, MODEL NO.,"
1381 DISP "AND TYPE (E OR M)"
1385 DISP "INPUT ''0' IF INFO IS UNKNOWN"
1390 INPUT W,A,S,N,L$
1391 PRINTER IS 701,76
1400 PRINT "WATER TEMP=";W,,"AIR TEMP=";A,,"SER. NO.=";S
,,"MODEL NO.=";N,,"TYPE ";L$
1410 GOTO 9996
2501 REM *SHUNT*
2502 CLEAR @ DISP "INPUT A PERCENTAGE OF RESONANT FREQ.
TO USE TO GET SHUNT (BLOCKED) VALUES."
2503 DISP "INPUT A VALUE FROM 0 TO 1."
2504 INPUT B1
2513 CLEAR @ BEEP @ DISP "WE ARE FINDING SHUNT VALUES FO
R G/B OR R/X."
2515 A$="FR" @ B$="HZ" @ S1=1
2519 IF T$="M" THEN 2525
2520 IF M=2 THEN 2522
2521 F=F0*B1 @ GOTO 2535
2522 F=F1*B1 @ GOTO 2535
2525 IF M=2 THEN 2527
2526 F=F8-B1*F8 @ GOTO 2535
2527 F=F9-B1*F9
2535 D$=VAL$(F)
2537 OUTPUT 717 ;A$,D$,B$
2538 WAIT 1000
2540 DISP "SET DRANETZ FREQ. SCALE TO COVER FREQ. ON SYN
THESIZER.ZERO METERS.SET ON FS.(CONT)"
2541 PAUSE
2542 DISP "HERE WE GET THE NORMALIZATION FACTORS."
2543 OUTPUT 709 ;"VT1"
2548 GOSUB 8549
2550 G,B,R,X=0
2551 A$="FR" @ B$="HZ" @ D$=VAL$(F)
2553 OUTPUT 717 ;A$,D$,B$
2561 CLEAR @ DISP "SET DRANETZ ON Y,SET SCALE,SET ON NOR
M FOR FILTER + PHASE,PLUG IN TRANSDUCER."
2562 BEEP @ DISP "ENTER SCALE FACTOR IN MICROMHOS.SAME S
CALE AS FOR DATA.(WE GET SHUNT G/B)"
2564 INPUT S8@ CLEAR @ DISP "I AM WORKING TO GET SHUNT V
ALUES" @ BEEP
2565 FOR I=1 TO 10
2566 OUTPUT 717 ;A$,D$,B$
2567 WAIT 1000
```

```
2568 OUTPUT 709 ;"AC3"
2569 ENTER 709 ; M(I)
2570 G=G+M(I)
2571 OUTPUT 709 ;"AC4"
2572 ENTER 709 ; N(I)
2573 B=B+N(I)
2574 NEXT I
2575 G=G/(I-1) @ B=B/(I-1)
2576 G=G*S8/N8 @ B=B*S8/N9 @ BEEP
2578 DISP "SET DRANETZ ON Z;SET SCALE FOR MAX RESPONSE.M
OVE TRANS. INPUT. ENTER SCALE FACTOR"
2579 INPUT S8@ CLEAR @ DISP "I AM WORKING TO GET SHUNT V
ALUES"
2580 FOR I=1 TO 10
2581 OUTPUT 717 ;A$,D$,B$
2582 WAIT 1000
2583 OUTPUT 709 ;"AC3"
2584 ENTER 709 ; M(I)
2585 R=R+M(I)
2586 OUTPUT 709 ;"AC4"
2587 ENTER 709 ; N(I)
2588 X=N(I)+X
2589 NEXT I
2590 R=R/(I-1) @ X=X/(I-1)
2591 R=R*S8/N8 @ X=X*S8/N9
2592 IF T$="M" THEN 2610
2595 IF M=1 THEN 2600
2596 R9=R @ X9=X @ C9=C @ B9=B @ GOTO 2601
2600 G0=G @ B0=B @ R0=R @ X0=X
2601 PRINT "SHUNT VALUES"
2602 PRINT USING 2603
2603 IMAGE 1/
2605 PRINT "G0=";G0,,"B0=";B0,,"R0=";R0,,"X0=";X0,,"G9="
;G9,,"B9=";B9,,"R9=";R9,,"X9=";X9
2606 PRINT @ GOTO 2630
2610 IF S1=2 THEN 2620
2611 J1=G @ J2=B @ J3=R @ J4=X
2612 IF M=2 THEN 2615
2613 F=F8+B1*F8 @ S1=2 @ GOTO 2550
2615 F=F9+B1*F9 @ S1=2 @ GOTO 2550
2620 G=.5*(G+J1) @ B=.5*(B+J2) @ R=.5*(R+J3) @ X=.5*(J4+
X) @ GOTO 2595
2630 GCLEAR @ CLEAR @ BEEP
2635 DISP "ENTER ''1' IF ALL IS WELL; ''2' IF YOU NEED A R
EPEAT."
2640 INPUT Y
2645 IF Y=2 THEN 2501
2650 RETURN
7000 REM **F-Q**
7001 GCLEAR @ CLEAR
```

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7005 DISP "ENTER LOWER, UPPER FREQ. FOR SWEEP.IF RESONAN
CE UNKNOWN USE 10000,200000. (F1,F2)"
7010 INPUT F4,F2
7011 DISP "ENTER RMS VOLTAGE NEEDED.(3000 MV FOR LOW FRE
Q. AS LOW AS 2000 MV FOR HIGH)"
7012 INPUT A@ A1$=VAL$(A)
7020 CLEAR @ BEEP
7025 A$="AM" @ B$="MR"
7035 OUTPUT 717 ;A$,A1$,B$
7040 OUTPUT 709 ;"AC3VT3"
7045 F3=CEIL((F2-F4)/300)
7060 CLEAR @ DISP "I AM WORKING TO GET THE SPECTRUM DATA
 FOR YOU,THEN WILL SHOW & MAKE A PLOT"
7065 FOR I=1 TO 300
7070 D(I,1)=F4+I*F3
7075 A$="HZ" @ B$="FR"
7083 D$=VAL$(D(I,1))
7085 OUTPUT 717 ;B$,D$,A$
7090 OUTPUT 709 ;"AC3VT3"
7095 WAIT 100
7100 ENTER 709 ; D(I,2)
7105 NEXT I
7110 F5=F4-.1*(F2-F4) @ F6=F2+.1*(F2-F4)
7115 F6=F2+.1*(F2-F4)
7119 PLOTTER IS 1 @ GCLEAR @ CLEAR
7125 SCALE F5,F6,-.1,1.2
7130 XAXIS 0,2000,F4,F2
7135 YAXIS F4,.1,-.1,1.2
7140 FOR I=1 TO 300
7145 PENUP
7150 PLOT D(I,1),D(I,2)
7155 NEXT I
7158 GRAPH @ COPY
7160 DISP "NEED ANOTHER RUN? (1=YES,2=NO)"
7161 INPUT Y
7162 IF Y=1 THEN 7005
7163 CLEAR @ GCLEAR @ BEEP
7165 DISP "ENTER DECISION POINT FOR AMPLITUDE (0 TO 1.2)
.(LESS THAN THE MAX DISPLAYED)."
7170 INPUT S@ CLEAR @ BEEP
7180 PRINT "AMPLITUDE IN VOLTS";"   FREQUENCY"
7181 PRINT
7190 FOR I=1 TO 300
7195 IF D(I,2)<S THEN 7210
7200 PRINT USING 7205 ; D(I,2),D(I,1)
7205 IMAGE 1X,D.DDDDDDDD,10X,DDDDDD.DD
7210 NEXT I
7215 PRINT USING 7220
7220 IMAGE 3/
7225 CLEAR @ BEEP
```

```
7226 DISP "IF YOU ARE READY TO CONTINUE ENTER ''1''; OTHER
WISE ENTER ''2''."
7227 INPUT Y
7228 IF Y=2 THEN 7160
7235 DISP "WHAT IS CENTER FREQ, HALFWIDTH TO CONSIDER?"
7236 INPUT F,N@ CLEAR @ BEEP
7240 DISP "I AM WORKING TO GET GOOD FREQ AND Q DATA"
7241 FOR I=1 TO 300
7242 D(I,1)=F-N+I*N/150
7243 A$="HZ" @ B$="FR"
7245 D$=VAL$(D(I,1))
7255 OUTPUT 717 ;B$,D$,A$
7260 OUTPUT 709 ;"AC3VT3"
7265 WAIT 100
7270 ENTER 709 ; D(I,2)
7275 NEXT I
7285 CLEAR @ GCLEAR @ DISP "I AM FINDING THE ABSOLUTE MA
X AND FREQ UPPER AND LOWER"
7290 B1,B4=0 @ H,H1,H2,H3,H4=1
7295 B2,B3=50
7300 FOR I=2 TO 300
7310 IF D(I,2)<D(H,2) THEN 7340
7315 IF D(I,2)=D(H,2) THEN 7325
7325 A6=D(I,2) @ F6=D(I,1) @ H=I
7340 NEXT I
7345 A7=A6/SQR(2)
7350 FOR I=1 TO H
7355 IF A7=D(I,2) THEN 7405
7360 IF A7<D(I,2) THEN 7385
7365 IF D(I,2)<B1 THEN 7425
7370 B1=D(I,2) @ H1=I @ GOTO 7425
7385 IF D(I,2)>B2 THEN 7400
7390 B2=D(I,2) @ H2=I
7400 GOTO 7425
7405 B1,B2=D(I,2) @ H1,H2=I @ F7=D(H2,1) @ GOTO 7440
7425 NEXT I
7430 X=(A7-B1)/(B2-B1)
7435 F7=X*(D(H2,1)-D(H1,1))+D(H1,1)
7440 FOR I=H TO 300
7445 IF A7=D(I,2) THEN 7495
7450 IF A7>D(I,2) THEN 7475
7455 IF D(I,2)>B3 THEN 7470
7460 B3=D(I,2) @ H3=I
7470 GOTO 7515
7475 IF D(I,2)<=B4 THEN 7490
7480 B4=D(I,2) @ H4=I
7490 GOTO 7515
7495 B3,B4=D(I,2) @ H3,H4=I
7505 L5=D(H3,1)
7510 GOTO 7530
```

```
7515 NEXT I
7520 X=(A7-B4)/(B3-B4)
7525 L5=-(X*(D(H4,1)-D(H3,1)))+D(H4,1)
7530 Q=F6/(L5-F7)
7535 PRINT "CENTER FREQ IS ";F6
7536 PRINT "Q IS ";Q
7538 DISP "IF YOU ARE READY TO PROCEED, ENTER ''1''. TO RE
RUN FOR BETTER VALUES, ENTER ''2''."
7539 INPUT Y
7540 IF Y=2 THEN 7235
7545 RETURN
8100 REM **DATA LIST**
8101 PRINTER IS 2
8102 FOR I=99 TO 199
8103 PRINT USING 8105 ; D(I,1),D(I,2),D(I,3)
8105 IMAGE DDDDDD.D,2X,D.DDDE  ,2X,D.DDDE
8106 NEXT I
8107 PRINT USING 8108
8108 IMAGE 3/
8110 RETURN
8200 REM **PLOT RE**
8201 GCLEAR @ CLEAR
8202 H8=D(1,1)-.15*(D(300,1)-D(1,1))
8203 H9=D(300,1)+.1*(D(300,1)-D(1,1))
8205 PLOTTER IS 705 @ PEN 1
8209 SCALE H8,H9,-(.8*E),E+.25*E
8210 XAXIS 0,(D(300,1)-D(1,1))/10,D(1,1),D(300,1)
8211 YAXIS D(1,1),E/5,-(.8*E),E+.2*E
8212 PENUP
8215 FOR I=1 TO 300
8216 PLOT D(I,1),D(I,2)
8217 NEXT I
8218 PENUP @ DEG @ LDIR 0,SIN(90)
8221 FOR L1=D(1,1) TO D(300,1) STEP (D(300,1)-D(1,1))/10
 @ PENUP
8222 MOVE L1,-(.18*E)
8223 LABEL INT(L1)
8224 NEXT L1
8226 LDIR 0 @ PENUP
8227 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-(.7*E)
8228 LABEL "FREQUENCY (HZ)"
8230 PENUP @ PEN 1
8232 LDIR 0
8234 FOR L1=-(.8*E) TO E+.2*E STEP E/5 @ PENUP
8235 MOVE D(1,1)-.09*(D(300,1)-D(1,1)),L1
8236 LABEL INT(L1)
8237 NEXT L1
8240 LDIR 0,SIN(90)
8241 MOVE D(1,1)-.1*(D(300,1)-D(1,1)),.1*E
8243 LABEL R$
```

```
8250 RETURN
8300 REM **PLOT IM**
8301 GCLEAR @ CLEAR
8303 H8=D(1,1)-.15*(D(300,1)-D(1,1))
8304 H9=D(300,1)+.1*(D(300,L)-D(1,1))
8305 L=MAX(ABS(E5),ABS(E3))
8306 PLOTTER IS 705 @ PEN 1
8312 SCALE H8,H9,-L-.5*L,L+.25*L
8313 XAXIS 0,(D(300,1)-D(1,1))/10,D(1,1),D(300,1)
8314 YAXIS D(1,1),L/5,-L-.2*L,L+.2*L
8315 PENUP
8318 FOR I=1 TO 300
8325 PLOT D(I,1),D(I,3)
8330 NEXT I
8331 PENUP @ DEG @ LDIR 0,SIN(90)
8333 FOR L1=D(1,1) TO D(300,1) STEP (D(300,1)-D(1,1))/10
 @ PENUP
8335 MOVE L1,-L-.2*L
8336 LABEL INT(L1)
8337 NEXT L1
8340 LDIR 0 @ PENUP
8341 MOVE D(1,1)+.2*(D(300,1)-D(1,1)),-L-.4*L
8342 LABEL "FREQUENCY (HZ)"
8345 PENUP @ PEN 1 @ LDIR 0
8352 FOR L1=-L-.2*L TO L+.2*L STEP L/5 @ PENUP
8355 MOVE D(1,1)-.09*(D(300,1)-D(1,1)),L1
8356 LABEL INT(L1)
8357 NEXT L1
8360 PENUP @ PEN 1 @ LDIR 0,SIN(90)
8361 MOVE D(1,1)-.1*(D(300,1)-D(1,1)),-(L*.5)
8368 LABEL G$
8380 RETURN
8400 REM **CIRCLES**
8401 GCLEAR @ CLEAR
8402 L1=MAX(ABS(E3),ABS(E5))
8403 L=MAX(ABS(E),L1)
8404 PLOTTER IS 705 @ PEN 1
8406 SCALE 1.25*(-L-.1*L),1.25*(L+.1*L),-L-.2*L,L+.15*L
8407 XAXIS 0,L/5,-L-.1*L,L+.1*L
8408 YAXIS 0,L/5,-L-.1*L,L+.1*L
8409 PENUP @ PEN 1
8411 FOR I=1 TO 300
8412 PLOT D(I,2),D(I,3)
8413 NEXT I
8414 PENUP
8415 LDIR 0 @ PEN 1 @ PENUP
8416 MOVE -(L*.5),-L-.1*L
8418 LABEL H$
8420 PENUP @ PEN 1 @ DEG
8425 LDIR 0,SIN(90)
```

```
8426 FOR L1=-L-.1*L TO L+.1*L STEP L/5 @ PENUP
8427 MOVE L1,-L
8428 LABEL INT(L1)
8429 NEXT L1
8435 LDIR 0 @ PEN 1 @ PENUP
8436 FOR L1=-L-.1*L TO L+.1*L STEP L/5 @ PENUP
8437 MOVE -(.866*L),L1
8438 LABEL INT(L1)
8439 NEXT L1
8445 LDIR 0,SIN(90)
8446 MOVE -(.95*L),-(.3*L)
8448 LABEL G$
8450 RETURN
8549 REM **NORM**
8550 N8,N9=0
8551 FOR I=1 TO 10
8557 WAIT 500
8558 OUTPUT 709 ;"AC3"
8559 ENTER 709 ; N(I)
8560 N8=N8+N(I)
8565 OUTPUT 709 ;"AC4"
8566 ENTER 709 ; M(I)
8567 N9=N9+M(I)
8568 NEXT I
8569 N8=N8/(I-1)
8570 N9=-(N9/(I-1))
8572 PRINT USING 8573
8573 IMAGE 3/
8575 RETURN
8600 REM **VALUES**
8601 CLEAR @ BEEP
8605 IF L2=1 AND M=2 THEN 8610
8606 IF L2=1 AND M=1 THEN 8611
8607 IF L2=2 AND M=1 THEN 8612
8608 IF L2=2 AND M=2 THEN 8613
8610 F6=F1 @ Q=Q1 @ GOTO 8615
8611 F6=F0 @ Q=Q0 @ GOTO 8615
8612 F6=F8 @ Q=Q8 @ GOTO 8615
8613 F6=F9 @ Q=Q9
8615 DISP "PLEASE SELECT THE HALFWIDTH OF INTEREST TO CO
LLECT DATA.(ENTER HALFWIDTH)"
8616 INPUT N @ CLEAR @ DISP "I AM COLLECTING THE DATA."
8625 FOR I=1 TO 300
8629 D(I,1)=F6-N+I*N/150
8630 A$="FR" @ B$="HZ"
8632 D$=VAL$(D(I,1))
8633 OUTPUT 717 ;A$,D$,B$
8634 WAIT 250
8635 OUTPUT 709 ;"AC3VT3"
8636 ENTER 709 ; H8
```

```
8637 D(I,2)=H8*S8/N8
8638 OUTPUT 709 ;"AC4VT3"
8639 ENTER 709 ; H9
8640 D(I,3)=H9*S8/N9
8641 NEXT I
8682 CLEAR @ DISP "I AM FINDING MIN/MAX VALUES & ASSOC.
FREQS"
8683 GOSUB 8700
8684 IF L2=2 THEN 8687
8685 PRINT "GMAX=";E,,"FGMX=";E1,,"BGMX=";E2,,"EMX=";E3,
,"FBMX=";E4,,"BMI=";E5,,"FBMI=";E6
8686 GOTO 8697
8687 PRINT "RMAX=";E,,"FRMX=";E1,,"XRMX=";E2,,"XMX=";E3,
,"FXMX=";E4,,"XMI=";E5,,"FXMI=";E6
8697 DISP "IF ALL IS WELL, ENTER ''1'. ENTER ''2' TO RETAK
E DATA."
8698 INPUT Y
8699 RETURN
8700 REM **MAXMIN**
8703 H,H1,H2=50
8705 E=D(50,2) @ E1,E4,E6=D(50,1) @ E2,E3,E5=D(50,3)
8706 FOR I=51 TO 250
8710 IF D(I,2)<D(H,2) THEN 8725
8711 IF D(I,2)=D(H,2) THEN 8720
8720 E=D(I,2) @ E1=D(I,1) @ E2=D(I,3) @ H=I
8725 IF D(I,3)<D(H1,3) THEN 8740
8726 IF D(I,3)=D(H1,3) THEN 8735
8735 E3=D(I,3) @ E4=D(I,1) @ H1=I
8740 IF D(I,3)>=D(H2,3) THEN 8751
8745 H2=I @ E5=D(I,3) @ E6=D(I,1)
8751 NEXT I
8760 J1=D(H,2) @ J2=(D(H+1,2)-D(H-1,2))/2 @ J3=(D(H+1,2)
+D(H-1,2)-2*J1)/2
8762 F6=-(J2/(2*J3))
8765 A=J1+J2+F6+J3*F6^2
8770 F6=D(H,1)+F6*(D(H,1)-D(H-1,1))
8775 E1=F6 @ E=A
8788 D=ABS(E3-E5)
8789 IF M=2 THEN 8793
8790 IF L2=1 THEN 8792
8791 D3=D @ GOTO 8796
8792 D1=D @ GOTO 8796
8793 IF L2=1 THEN 8795
8794 D4=D @ GOTO 8796
8795 D2=D
8796 PRINT "D1=";D1,,"D2=";D2,,"D3=";D3,,"D4=";D4
8799 RETURN
9000 REM **CALC-A**
9001 PRINTER IS 701,76
9002 PRINT @ PRINT
```

```
9003 PRINT "VALUES MEASURED IN AIR FROM ";S$;" DATA"
9004 PRINT
9011 PRINT "BLOCKED CAPACITANCE= ";ABS(C0);" FARADS AT "
;F;"HZ"
9012 PRINT "ELECTRICAL QUALITY FACTOR = ";Q0
9013 PRINT "MECHANICAL QUALITY FACTOR = ";Q8
9014 PRINT "ELECTRICAL RESONANCE =";F0;" HZ"
9015 PRINT "MECHANICAL RESONANCE = ";F8;" HZ"
9016 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9017 PRINT "STATIC COUPLING COEFFICIENT= ";K1
9021 PRINT "BLOCKED RESISTANCE=";R0;"OHMS"
9031 PRINT USING 9032
9032 IMAGE 2/
9050 RETURN
9100 REM **CALC-W**
9101 PRINTER IS 701,76
9102 PRINT @ PRINT
9103 PRINT "VALUES  FOR MEASUREMENTS IN WATER FROM ";S$;
" DATA"
9104 PRINT
9111 PRINT "BLOCKED CAPACITANCE = ";ABS(C0);" FARADS AT
";F;"HZ"
9112 PRINT "ELECTRICAL QUALITY FACTOR = ";Q1
9113 PRINT "MECHANICAL QUALITY FACTOR = ";Q9
9114 PRINT "ELECTRICAL RESONANCE = ";F1;" HZ"
9115 PRINT "MECHANICAL RESONANCE = ";F9;" HZ"
9116 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9119 PRINT "FREQUENCY OF OPTIMUM EFFICIENCY = ";W0;" HZ"

9120 PRINT "MECHANICAL POWER UTILIZATION FACTOR";ABS(P6)

9121 PRINT " STATIC COUPLING COEFFICIENT=";K1
9122 PRINT "BLOCKED RESISTANCE =";R9;"OHMS"
9132 PRINT USING 9133
9133 IMAGE 3/
9150 RETURN
9200 REM **CALC-A/M**
9201 PRINTER IS 701,76
9202 PRINT @ PRINT
9203 PRINT "VALUES MEASURED IN AIR FROM ";S$;" DATA"
9204 PRINT
9211 PRINT "BLOCKED INDUCTANCE= ";ABS(L0);" HENRIES AT "
;F6;"HZ"
9212 PRINT "ELECTRICAL QUALITY FACTOR = ";Q0
9213 PRINT "MECHANICAL QUALITY FACTOR = ";Q8
9214 PRINT "ELECTRICAL RESONANCE =";F0;" HZ"
9215 PRINT "MECHANICAL RESONANCE = ";F8;" HZ"
9216 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
```

```
NT = ";K
9217 PRINT "BLOCKED RESISTANCE= ";R
9231 PRINT USING 9232
9232 IMAGE 2/
9250 RETURN
9300 REM **CALC-W/M**
9301 PRINTER IS 701,76
9302 PRINT @ PRINT
9303 PRINT "VALUES  FOR MEASUREMENTS IN WATER FROM ";S$;
" DATA"
9304 PRINT
9311 PRINT "BLOCKED INDUCTANCE = ";ABS(L0);" HENRIES AT
";F6;"HZ"
9312 PRINT "ELECTRICAL QUALITY FACTOR = ";Q1
9313 PRINT "MECHANICAL QUALITY FACTOR = ";Q9
9314 PRINT "ELECTRICAL RESONANCE = ";F1;" HZ"
9315 PRINT "MECHANICAL RESONANCE = ";F9;" HZ"
9316 PRINT "DYNAMIC ELECTROMECHANICAL COUPLING COEFFICIE
NT = ";K
9318 PRINT "POTENTIAL EFFICIENCY = ";P5
9319 PRINT "FREQUENCY OF OPTIMUM EFFICIENCY = ";W0;" HZ"

9320 PRINT "MECHANICAL POWER UTILIZATION FACTOR";ABS(P6)

9322 PRINT USING 9323
9323 IMAGE 3/
9350 RETURN
9998 DISP "THE END"
9999 END
```

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